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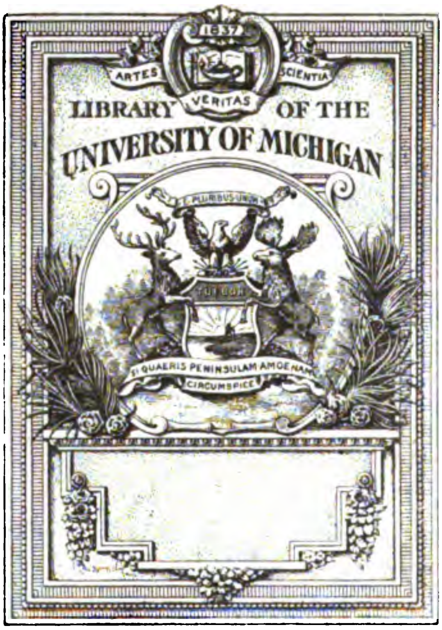
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U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ANIMAL INDUSTRY.—BULLETIN 151.
A. D. MELVIN, CHIEF OF BUREAU.

A STUDY OF THE GASES OF EMMENTAL CHEESE.

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OCT 16 1912

BY

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Chemist, Dairy Division.

WASHINGTON:
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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ANIMAL INDUSTRY,
Washington, D. C., April 23, 1912.

SIR: I have the honor to transmit, and to recommend for publication in the bulletin series of the bureau, the accompanying manuscript entitled "A Study of the Gases of Emmental Cheese," by Dr. William Mansfield Clark, chemist in the Dairy Division.

The so-called "eyes" in Swiss cheese are, as is well known, its most prominent characteristic, and its commercial value is largely dependent upon the proper size and spacing of these eyes. Furthermore, much depreciation in the value of this popular variety of cheese, in both the domestic and foreign kinds, is known to exist because of defects in eye formation. The experimental work herein described concerns the chemical contents of these eyes, and although considerable work has been done in Europe with the object of discovering the cause of eye formation, there has hitherto been no investigation made of the gases which are immediately concerned in the process. Dr. Clark's studies are therefore calculated to be of value to the scientific as well as the practical side of the industry.

Respectfully,

A. D. MELVIN,
Chief of Bureau.

HON. JAMES WILSON,
Secretary of Agriculture.

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A STUDY OF THE GASES OF EMMENTAL CHEESE.

INTRODUCTION.

The "eyes" of Swiss or Emmental cheese are its most striking characteristic. Their formation is a fascinating subject to the biological chemist, because of a supposed localization of reactions generating considerable quantities of gas, and because of the production of a plasticity among the colloids of the cheese, which makes possible the peculiar mold of the cavities.

To the cheese maker the formation of the "eyes" is a matter of great importance, since their size and proper spacing determine in large measure the commercial value of the cheese. In certain districts of Wisconsin visited by the writer the dealers rely almost entirely upon these features, and, shortly after the eyes have reached their proper development, relieve the maker of further care. The American makers of Swiss cheese are, therefore, unable to attend to their cheeses in that mellow old age upon which so much of the fine flavor of a true Emmental cheese depends. However much this quick marketing is to be deprecated, the fact remains that it raises the relative importance of the eye formation and adds significance to whatever knowledge can be gained concerning the process.

Some years ago Băchler,[1] [a] cited by Jensen,[11] estimated that 25 per cent of the cheeses made in Switzerland were considerably reduced in value because of imperfect eye formation. How far this enormous loss has been lessened in recent years as a result of scientifically controlled manufacture can not be said, but in this country, where large numbers of Swiss are still using the antiquated methods of their forefathers, Băchler's estimate is probably not too high. The wide difference in market price between domestic and imported Swiss cheese bears out this statement.

Considerable work has been done in Europe in the effort to uncover the cause of eye formation, and, through the labors particularly of

---

[a] The reference figures relate to the list of references to literature at end of bulletin.

Von Freudenreich and Jensen, a well-founded theory has been proposed which will be discussed later. No one, however, has made a study of the gases which are themselves the immediate cause of the eye formation, and it was with the hope that such a study might furnish valuable data that the research herein described was undertaken. If nothing more is demonstrated than the composition of the gas in the eyes, this alone justifies the work, for the extensive researches on the eye formation in Emmental cheese have led to but one conclusion that can be called positive, and that is that a final explanation will be reached only when every phase of the subject has been submitted to exact quantitative study.

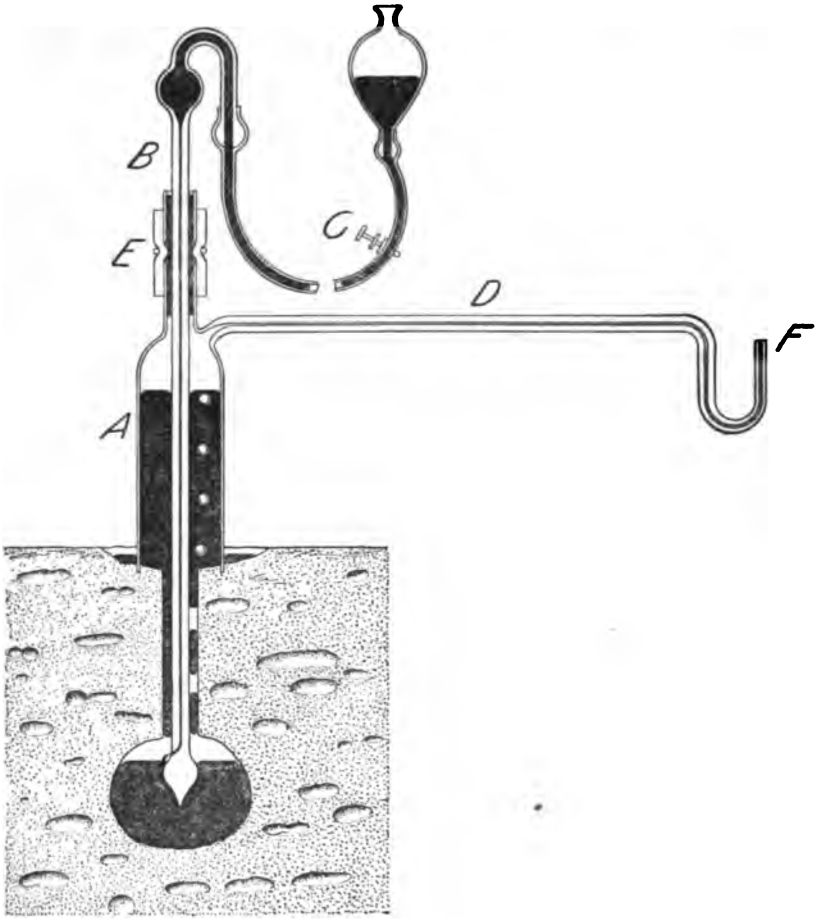

FIG. 1.—Apparatus for collecting gas from the eyes of Swiss or Emmental cheese.

DESCRIPTION OF APPARATUS AND METHODS OF COLLECTING THE GASES.

The collection of the gas in the eyes by cutting the cheese under a bell jar filled with water, as was done with Edam cheese by Boekhout and Ott de Vries,[3] is a simple and valuable method, but one which is hardly to be called accurate, owing to the high solubility of certain gases in water. In place of such a method an apparatus was devised for collecting the gas over mercury. This is shown in figure 1, the procedure being as follows:

METHOD I.

The glass cylinder A is forced a short distance into the body of the cheese until it is firmly held. It is then clamped in position. Around the outside the cheese is cut away sufficiently to leave a channel into which mercury moistened with mercuric chlorid solution is poured. This forms a seal preventing entrance of air. The head of the shaft B is now resting on the surface of the cheese. Through its capillary mercury is run into the cylinder, displacing the air until it finally runs out of the side arm D and up through the annular space between the shaft and the shoulder of the cylinder. The short length of thick rubber tubing at E is then very tightly bound with a rubber band, leaving mercury in the small cup above, and thus effectually closing this opening against the entrance of air. When the cylinder and side arm are thus completely filled with mercury, a receptacle filled with mercury is brought over the end of the side arm (in a mercury trough, of course) and serves to retain the collected gas until the time of the analysis. After these preparations the shaft is pushed down into the cheese. When it punctures an eye this can readily be felt. Since the head of the shaft is larger than the shank, there is left an annular space for the escape of the gas. This gas is displaced from the eye partially by the mercury of the cylinder, which finds its way to the lower level, but more largely by the mercury which runs in through the capillary in the shaft. The exit of this is prevented from becoming clogged with cheese by carefully blowing it out just behind the head, as shown in the diagram. When the gas is displaced from the eye it is displaced from the cylinder into the receiver by continuing to run in mercury through the shaft from the reservoir C. Between this reservoir and the shaft is placed a bulb which prevents the mercury from sweeping in bubbles of air.

In the samples of gas collected with this apparatus seldom was more than a trace of oxygen found. This in itself shows that the gas was obtained without contamination by air.

METHOD II.

For the collection of gas from "pinholes" the foregoing apparatus was of little use except in one instance to be mentioned later. To collect the gas from this form of hole, as well as the gas in the body of the cheese, the apparatus shown in figure 2 was used, as follows:

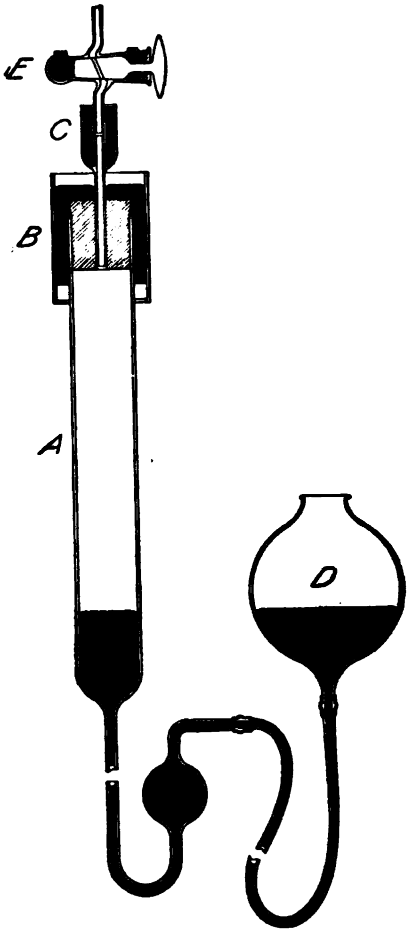

FIG. 2.—Apparatus for pumping gas from cheese.

Samples of cheese taken with a trier were introduced into the glass cylinder A. The rubber stopper at B, attached to the mercury vacuum pump with or without the intermediate connection C, was forced in securely and protected from leakage by the mercury seal. Upon raising the leveling bulb D the cheese was flooded with mercury and the surrounding air was forced over into the pump until the mercury stood at the stopcock E. To prevent bubbles of air being trapped under the cheese the lower ends of the plugs were sharply beveled. Bubbles of air of course adhered to the rough surface of the cheese and its smaller exposed cavities. This error is inherent in the method, but was reduced by suddenly dropping the leveling bulb with the stopcock E closed, and then driving the air, which had expanded into the vacuum, past the open stopcock.

The glass tube with its trap which connects A with the leveling bulb was made sufficiently long so that D might be lowered the barometric distance below A, and thus leave the cheese exposed to a fairly high vacuum even before the pumping commenced. After exhausting the pump up to E this cock was opened, and the gas pumped from the cheese and delivered into a receiver.

The mercury pump used in this as in other operations to be described later was Antropoff's modification of the Topler. A full description of the pump and its appurtenances will appear in the account of another investigation.

METHOD OF ANALYSIS.

The gas was analyzed with a special set of burettes and pipettes designed for the analysis of small quantities of gas produced by bacteria. A few of the first analyses were made with a burette specially designed for volumes as low as 0.5 c. c. In all the analyses the confining liquid was mercury, and use was made of a device for extremely accurate separation of gas from absorbent.

Thirty-three per cent potassium hydroxid solution, in quantities appropriate for the volume of gas analyzed, served as absorbent for carbon dioxid. Hydrogen sulphid, after preliminary qualitative tests, was assumed to be absent, although it is of course possible that, if present originally in the gas, it may have been taken up by the mercury. That any of this gas occurs in the eyes is, however, very improbable, for its odor was never detected. For hydrogen sulphid and mercaptans the nose is many times more sensitive than is the spectroscope for sodium,[6] and unless the other and milder odors of Swiss cheese exercise a surprisingly intense hindrance to the detection of hydrogen sulphid and mercaptans we may justly say that these vapors were absent. With Nessler's reagent very slight traces of ammonia were detected. For oxygen alkaline pyrogallol or long-continued contact with phosphorus was used. Combustible gases were estimated in several ways. Explosion with oxygen, in the presence of electrolytic gas when necessary, was used in several instances. For one case combustion with a platinum sponge was tried. For the small percentages of combustible gases found the method of Dennis and Hopkins[5] was found to be the most satisfactory. This consists, essentially, in leading the gas slowly into a measured volume of oxygen and there burning it slowly and quietly with a platinum wire heated by an electric current.

TABLE 1.—*Analyses of gas collected by puncturing apparatus from eyes of Swiss (Emmental) cheese—Method I.*

Designation of cheese.	Total volume of gas collected.	Contraction—			Composition.					Description of cheese.
		Due to absorption with KOH.	Due to absorption for O_2.	Due to combustion.	CO_2.	O_2.	Hydrocarbons.	H_2.	N_2.	
	C. c.	*C. c.*	*C. c.*	*C. c.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	
a	0.96	0.55	......	......	57.3	......	......	......	......	Imported, eyes normal.
b	2.73	2.29	0.00	......	83.9	0.0	......	......	......	Do.
c	1.66	1.11	.01	0.10	66.9	Trace.	(?)	4.00	29.1	Imported, eyes (?).
d	4.77	2.44	.02	.02	51.2	Trace.	0.0	Trace?	48.8	Imported, eyes normal.
e	1.25	1.00	.00	.00	80.0	0.0	0.0	0.0	20.0	Do.
f	3.44	2.23	.00	.60	64.8	0.0	0.0	11.6	23.6	Domestic, eyes thickly crowded.
	4.02	2.52	......	.45	62.7	......	0.0	7.5	29.8	
g	15.24	13.77	.00	.76	90.4	0.0	Trace?	3.3	6.3	Do.
h	7.56	6.14	.02	.43	81.2	Trace.	0.0	3.7	15.1	Imported, eyes thickly crowded.
	4.99	4.04	.03	.30	80.9	0.6	0.0	4.0	14.5	
i	14.47	12.91	.03	.00	89.2	0.2	0.0	0.0	10.6	Excellent imported, eyes very regular.
	9.99	8.96	.01	.09	89.5	Trace.	0.0	0.6	9.8	
j	5.42	3.04	.02	.06	56.0	Trace.	0.0?	Trace?	44.0	Imported, large hole.
29.61	4.96	2.35	.01	3.63	47.4	Trace.	0.0	48.8	3.8	Very gassy in press.

The analyses of the gas collected by Method I are given in Table 1, and of that collected by Method II in Table 2. All volumes are for 0° C. and 760 mm. When the gases were collected from a cheese procured at the market, a sufficiently large slice was purchased to prevent undue exposure of the eyes, and this was carried immediately the short distance to the laboratory, and the gas at once collected. In most cases the shaft punctured or grazed more than one eye, so that the analysis gives the true average for several eyes.

TABLE 2.—*Analyses of gas collected by pumping from Swiss (Emmental) cheese—Method II.*

No. of cheese.	Time pumping.	Total gas collected.	Weight of cheese evacuated.	Amount of gas per 100 grams of cheese.	Composition.				Description of cheese.
					CO_2.	O_2.	H_2.	N_2.	
	Hours.	*C. c.*	*Grams.*	*C. c.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	
3	20	2.36	....	....	76.3	1.7	0.0	22.0	Almost blind. Several small holes, either pinholes or inhibited eyes.
39-45	....	2.31	....	....	77.5	2.6	0.0	19.9	Do.
39-11-2	20	6.41	....	....	80.8	2.0	0.0	17.2	Do.
46-4-1	....	3.20	50	6.40	50.6	1.0	0.0	48.4	Do.
W2	20	13.60	53	25.7	84.5	2.2	0.0	13.3	Fine domestic cheese just beginning eye development.

DISCUSSION OF THE ANALYSES.

If the values obtained in this study of the gases found in the eyes of Swiss cheese are compared with the values obtained by Boekhout and Ott de Vries [2] for the gases in Edam cheese, it is seen that the latter obtained much lower percentages of carbon dioxid and correspondingly higher percentages of nitrogen. The explanation becomes apparent when it is remembered that Boekhout and Ott de Vries collected the gas over water, while in this investigation it was collected over mercury. The two methods were compared in the case of cheese h, as follows:

Method.	CO_2.	O_2.	H_2.	N_2.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Collection over mercury	81.2	Trace.	3.7	15.1
Collection over mercury	80.9	0.6	4.0	14.5
Collection over water	34.8	1.9	1.9	61.4

This result is what might have been expected, namely, an absorption of much carbon dioxid and a little hydrogen by the water, and, in return, an increase in the amount of oxygen as well as an increase in percentage of nitrogen. Boekhout and Ott de Vries have themselves called attention to this, and claim only qualitative value for their results. The types of holes from which they isolated gas were small cracks corresponding to the Emmental "riszler," small round holes, and large cracks termed "knijpers."

Qualitatively the composition of the gases was the same, namely, carbon dioxid, hydrogen, nitrogen, and oxygen. Of these they eliminated oxygen as due to contamination. In the case of the "knijpers," or large cracks, 52 to 249 c. c. of gas were collected instead of 5 to 22 c. c. as in the case of the smaller holes. Assuming that the same volume of water was used, we would expect a truer value to be obtained for the analysis of the larger volumes, in which case the attention is struck by the large percentage of hydrogen. The significance of this will become apparent when the results on Emmental cheese have been assembled.

It is clear from the analyses of gas found in Emmental cheese that carbon dioxid and nitrogen are the chief constituents of the gas found in normal eyes. The oxygen in most cases is hardly more than would be expected to come from the minute bubbles or surface layers which adhere to the glass walls of the apparatus. To what gas the contraction after explosion with oxygen is to be ascribed is a difficult question to settle. In some cases, where the contraction was sufficiently large to justify further absorption with potassium hydroxid, the absence of any further contraction in volume justifies the conclusion that the combustible gas was chiefly hydrogen. In other cases the small contraction might have been due to any one of a number of gaseous combustions.

For further information it was decided to examine specimens of gas spectroscopically. The gas freed from carbon dioxid and possible oxygen was passed over phosphorus pentoxid into a dry, exhausted Plücker tube. The discharge of an induction coil was then passed between aluminum terminals, and the spectrum observed with a prism spectroscope. At the same time comparison was made with the spectrum of a similar tube containing pure hydrogen. Minute traces of hydrogen are to be expected when metal terminals are used, but, with the low resolving power of the spectroscope employed, the nitrogen spectrum so obscured the possibly present red line of hydrogen that it was not observed with specimens of pure nitrogen. A known sample of nitrogen containing about 0.05 per cent of hydrogen gave a brilliant hydrogen spectrum, whose intensity could be made more sharp at the expense of the nitrogen spectrum by suitable varying of the pressure.[15] The recognition of 0.05 per cent of hydrogen was therefore assured.

A small experimental cheese, which had begun an apparently normal eye formation and then ceased entirely, was pumped out by Method II and its gas submitted to spectroscopic examination. Slight evidences of hydrogen were observed. Samples of gas taken from cheeses which yielded 3 per cent of combustible gas gave very brilliant evidences of hydrogen.

In samples of gas taken from the normal eyes of two cheeses purchased on the market no hydrogen line was observed, nor was the hydrogen spectrum observed in the gases of a normal cheese evolved during the period of its maximum eye formation.

These results, though not extensive, are sufficient to show that hydrogen plays no rôle in the formation of normal eyes, provided we assume that any hydrogen formed has not escaped collection by rapidly diffusing through the cheese. To make sure of this point the following experiments were conducted:

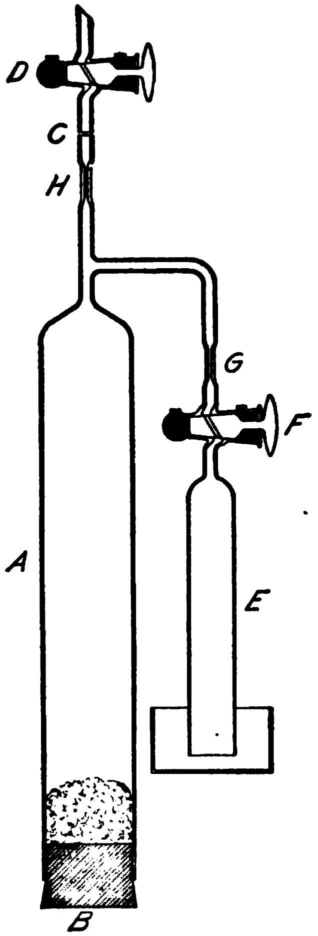

FIG. 3.—Apparatus for studying the absorption of oxygen by cheese.

Two cheeses purchased in Wisconsin were found to be developing normal eyes. These eyes, though too thickly scattered for the modern market standard, would have been declared typical some years ago. When each cheese was apparently at the height of its eye formation, plugs were taken, and introduced into the tube A, figure 3, without that part illustrated at the side and lettered G, F, and E. To guard as far as possible against infection in transference the trier was flamed, and the tube was sterilized at 170° C., with cotton plugs at B and C. After introducing the plugs of cheese they were followed by the flamed cotton plug and then a rubber stopper dipped in hot rubber cement. The stopper was forced in and held in place till the cement[a] had cooled, when several layers of the same cement were added to the exterior. This made a thoroughly gas-tight seal. The capillary end was now attached to the mercury pump by means of securely tied rubber tubing completely covered with a mercury seal. Then the tube was exhausted.

Forty-six grams from one of the Wisconsin cheeses were exhausted for two hours, during which time it continued to give off small quantities of gas. The pressure was finally reduced to 2 mm. (measured on a McLeod gauge). The stopcock D was then closed, and the tube allowed to remain in connection with the pump overnight. The next morning the pumping was resumed, and a pressure of 2 mm. again obtained. The gas which had collected overnight amounted to 7.23 c. c., N. T. P. Its analysis follows:

---

[a] The cement was made by heating rosin several days with as much fine-grade rubber as it would dissolve. Dr. Nutting, of the Bureau of Standards, who kindly furnished the receipt, stated that he had used this cement in refined vacuum work with entire satisfaction.

	C.c.
Original volume	7.23
Residue after absorption with KOH	.17
CO_2	7.05
Oxygen added up to	[a]2.28
Volume after combustion with heated platinum spiral	2.26
Contraction	.02

The tube was then sealed off in a blowpipe at the constriction H and kept for six days at 25° C. To collect the gas from this sealed tube the following method was used. The capillary tip of the seal was scratched with a diamond, and then pushed up into the tube leading from the pump as at C, figure 3. Connection was made with a rubber tube securely tied and covered with a mercury seal. Having exhausted the pump up to the tip of the seal, the tube was turned slightly and sharply. The tip was broken at the scratch, and communication established between A and the pump.

The gas thus collected at the end of six days amounted to 10.12 c. c. The tube was allowed to stand connected with the pump overnight, after which an additional 2.75 c. c. of gas were collected.

These two volumes were united and analyzed 99.3 per cent carbon dioxid. The residue was hardly sufficient to justify further analysis. It was made, however, and a minute contraction observed, which was hardly more than the experimental errors of transference.

Forty-five grams of the second Wisconsin cheese submitted to the same procedure as described above gave the following data:

	C.c.
Gas collected on first standing overnight	11.48
Residue after absorption with KOH	.22
CO_2	11.26
Residue after absorption with phosphorus	.22
Oxygen added up to	[a]2.41
Volume after combustion with heated platinum spiral	2.39

Tube sealed off and incubated six days at 25° C.

	C.c.
Gas collected after 6 days	9.29
Residue after absorption with KOH	.16
CO_2	9.13
Oxygen added up to	[a]4.91
Volume after combustion with hot platinum spiral	4.85
Gas collected after again standing overnight	5.33
Residue after absorption with KOH	Trace.

---

[a] This comparatively large volume was made necessary because of the disadvantageous form of the Dennis-Hopkins pipette used.

In the above analyses the contraction due to combustion was so small that further analyses to determine the products of combustion were impracticable. Nor was it necessary, for, even if the contraction were due to but one gas, for example hydrogen, the amount was such that this gas may be said to be without significance in the formation of eyes. Doubtless the contraction was in reality due to volatile organic bodies. The above experiments show that when all the gas from an actively gas-producing region is collected no significant amount of hydrogen is found, and thereby the contention is refuted that, in the analysis of gas in the eyes, hydrogen escaped detection because of its rapid diffusion out through the cheese.

Pains were taken in these studies to make a strenuous hunt for hydrogen for the following reason: In Emmental cheese there is what Duclaux has termed the "initial fermentation" during which the sugar inclosed in the curd undergoes bacterial decomposition. Several of the earlier workers on this cheese thought it was the gaseous fermentation of this sugar which caused the development of eyes. If so, one would expect to find the gas composed of a large percentage of hydrogen, since hydrogen is a characteristic product in the fermentation of sugars by bacteria. This deduction is of course not rigid, but, from our present knowledge of the gaseous fermentation of sugars by bacteria, it is highly probable.

Jensen[11] in 1898 pointed out clearly that the gaseous fermentation of sugar must not be looked upon as in any way directly connected with the production of normal eyes in Emmental cheese. He found no trace of sugar in a cheese five days old, although the normal eye formation had not yet begun. This confirms the analyses made by various authors. Jensen cited Klenze[13] as stating that the sugar disappears in 48 hours. But, while the sugar disappears rapidly, normal eyes seldom begin to develop before the eighth day, and reach the height of their development long after every trace of sugar has disappeared.

These facts alone demonstrate that the eye formation does not depend upon the presence of sugar. Additional reason for so believing is found in the results herein, in so far as the absence of hydrogen in the gas indicates an absence of gaseous sugar fermentation.

But it also follows from this reasoning that when a gaseous fermentation occurs while sugar is still present in the cheese, hydrogen is to be expected. Such a fermentation frequently occurs while the cheese is in press. Fortunately a cheese was obtained (No. 39–61) which was known to have given marked signs of gas while under press. From this cheese gas was collected by the previously described Method I, with the following analysis:

Total volume of gas collected	Cubic centimeters	4.96
Residue after absorption with KOH	do	2.61
CO_2	do	2.35
Residue after absorption with phosphorus	do	2.60

Oxygen added up to	Cubic centimeters	6.14
Volume after combustion with platinum spiral	do	2.51
Contraction	do	3.63
Residue after absorption with KOH	do	2.51
Hydrogen	per cent	48.80

Upon attempting to make a second puncture the mercury broke through into the hole previously made. The cheese was then opened, and found to be so spongy that the walls separating the individual cells were very thin—too thin to withstand the weight of mercury.

To obtain a second sample of gas for confirmatory analysis recourse was had to Method II of collecting gas, previously described. A high percentage of hydrogen was again found.

In the further study of this case 52 grams of the cheese were introduced into the vacuum tube described on page 14 and evacuated to 1 mm. pressure. There collected overnight 7.84 c. c. of gas.

Analysis:

	C. c.
Total volume	7.84
Residue after absorption with KOH	.28
Residue after absorption with phosphorus	.27
Oxygen added up to	1.08
Volume after combustion with platinum spiral	.99
Contraction	.09

The tube was then sealed off and kept nine days at 25° C. Upon opening it and pumping out the gas by the method previously described 7.49 c. c. of gas were collected. The residue after absorption with potassium hydroxid was only 0.07 c. c.

It is therefore apparent that the production of hydrogen, which was very active while the cheese was in press, had soon ceased, presumably with the disappearance of the sugar.

The occasional occurrence of hydrogen in small percentages, as shown in the table, generally accompanied eyes which in the writer's judgment were not typically normal. They were either crowded and distorted or associated with numerous pinholes. It is not, perhaps, incorrect to say that in all probability there had occurred in these cases a slight initial gaseous fermentation of the sugar, with the production of hydrogen which lingered to contaminate the gas of the normal fermentation.

An extremely interesting observation was made in the case of cheese i. (See Table 1, p. 11.) This was an excellent imported cheese with large and perfectly rounded eyes, well spaced in a body of fine texture and flavor. In the first analysis of the gas from these eyes no trace of a combustible gas was found. The second analysis gave 0.6 per cent of hydrogen. Upon exposing the eyes punctured it was observed that a slight crack extended to within a centimeter of one of the eyes punctured on the second collection. This crack was found to lead directly to a hole some 2 cm. in diameter, the irregular and apparently corroded walls of which proclaimed it distinctly abnormal.

It is of interest to note that in the case of cheese j, gas was obtained from a hole the size of one's fist, and that this contained practically no hydrogen. The appearance of this hole was that of a strictly normal eye except in size.

It was hoped that the gas of a typical "blow hole" could be obtained. For this purpose a cheese containing such a hole was purchased in Wisconsin. When it arrived at the laboratory it was found that the cheesemaker had punctured it.

From the results obtained it is clear that there are at least two distinct types of gas formation.[a] The one is highly detrimental, and is accompanied with hydrogen; the other is that demanded in a good Emmental cheese. One is dependent upon the presence of sugar; the other occurs in the absence of sugar.

The presence of hydrogen in considerable quantities in the gas isolated from Edam cheese by Boekhout and Ott de Vries is very suggestive of a gaseous fermentation of sugar, and to this Jensen[11] has ascribed the formation of gas holes in Edam cheese.

At this point it may be well to call attention to a source of error overlooked by various investigators in their attempts to establish the cause of any particular gas formation in cheese. Frequent examples are to be found in which gas production by bacteria in milk is interpreted to mean that these bacteria can produce gas in cheese. Although this may frequently be true, it must nevertheless be remembered that the two media differ not only in chemical constitution but also vary greatly in physical chemical condition.

Baumann,[3] for instance, attributed the formation of eyes in hard cheeses to *Bacillus diatrypeticus casei.* From an experiment in which this bacillus produced in milk gas containing 63 per cent of carbon dioxid and the remainder almost entirely hydrogen, Baumann concluded that the gas of normal as well as faulty eyes is carbon dioxid and hydrogen. The error of attributing the reactions of a bacillus when cultivated in milk, which contains sugar, to cheese, which after the initial fermentation contains no sugar, is so evident, and the error in stating that the gas of normal eyes contains hydrogen, without having first analyzed this gas, is so evident, that Baumann's conclusions might be left unnoticed at this late date were they not typical of several found in the more recent literature.

ABSORPTION OF OXYGEN.

In all the analyses no appreciable amount of oxygen was found. The presence of large percentages of nitrogen with this absence of oxygen raises the question, Does air diffuse into the cheese with absorption of oxygen? Evidence of an active absorption of oxygen was accidentally obtained. In attempting to study the gases produced in sealed tubes a faulty form of tube was first used, which evidently leaked. On attempting to exhaust, the lowest pressure which could be obtained was 3.6 mm. It was soon ascertained that there was no leak in the pump, but a leak in the tube was suspected. The tube was left connected with the pump (connecting stopcock closed) over night. The next morning 37.20 c. c. of gas was pumped out. The first portion of 19.15 c. c. gave 4.57 c. c. of carbon dioxid and 2.21 c. c. of oxygen. The residue was lost but was considered to be nitrogen. The second portion was then pumped out, and of the 18.05 c. c. thus collected there were 4.85 c. c. of carbon dioxid, 1.45 c. c. of oxygen, and the residue entirely nitrogen. The total oxygen amounted to 3.66 c. c., which, had it come by leakage, would have indicated an entrance of 13.7 c. c. of nitrogen. There was actually found 24.12 c. c. of nitrogen. This leaves 10.42 c. c. of nitrogen to be accounted for. The carbon dioxid amounted to only 9.42 c. c. and, since the ratio $\frac{10.42}{9.42}$ is much larger than that obtained in other similar pumpings where no leak occurred, it was suspected that oxygen had been absorbed.

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[a] This does not preclude there being a number of distinct fermentations or reactions of either type.

To definitely determine this the apparatus shown in figure 3 was used. With plugs of cotton at B, C, and in the bend above G, the tube was sterilized at 170° C. Then 28.5 grams from one of the Wisconsin cheeses were carefully taken with trier and spatula flamed to prevent contamination as far as possible, and the plugs introduced into A and sealed in as previously described. Mercury was drawn up into the tube E until it had just passed the stopcock F. After attachment had been made to the pump the whole was evacuated 5 hours and finally at a pressure of 1.2 mm. the capillary at H was sealed off in a blowpipe flame. There was introduced into E 7.47 c. c. N. T. P. of oxygen from a tank. At the same time a sample of the same gas was taken for analysis, and found to contain 98.1 per cent of oxygen. Upon opening the cock F atmospheric pressure forced the gas over into the tube A. The mercury behind this gas was allowed to rise until it had entered the capillary G. As close to this mercury as was possible G was then fused off with a blowpipe. There was left of the 7.47 c. c. introduced only a small bubble in the capillary, and this at reduced pressure. After 6 days at 25° C. the tube was opened by the usual method and the gas was pumped out and analyzed, with the following result:

	C. c.
Total volume of gas collected	11.90
Carbon dioxid	10.96
Oxygen	.53
Residue, all nitrogen	.41

From the percentage composition of the 7.47 c. c. of gas added at the beginning of the experiment it is known that 7.33 c. c. of oxygen was added. At the end of the experiment there remained only 0.53 c. c. of oxygen. There must, therefore, have been 6.80 c. c. of oxygen absorbed, or 0.239 c. c. per gram of cheese.

Such an active absorption of oxygen lends itself to the argument that the nitrogen of the eyes found its way there by the diffusion in of air. But, before such an argument can be considered valid, the following points must be determined: First, to what extent is cheese permeable to gases in general and nitrogen in particular? Second, how much of the nitrogen present is due to nitrogen dissolved in the cheese at the time of manufacture? Third, what evidences are there to show that the nitrogen does not arise in situ from bacterial or chemical reactions?

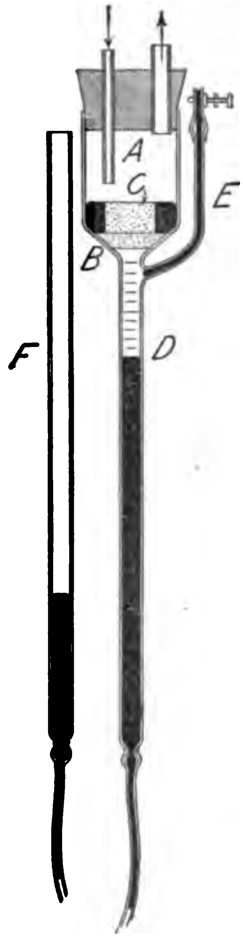

FIG. 4.—Device for ascertaining permeability of cheese to gases.

THE PERMEABILITY OF CHEESE TO GASES.

After various unsuccessful efforts to make an impermeable adhesive that would stick to cheese, and so enable a slice to be sealed into a diffusion apparatus, the following device was made (fig. 4):

At B a membrane of plaster of Paris was formed whose strength was reenforced by a perforated brass plate not shown in the diagram. This membrane was desiccated until its permeability was high, that of transfusion.[10]

Most of the air was forced out of D through the membrane and E by raising the mercury. A carefully taken disk of cheese was then placed on the plaster of Paris bed. It was gently held there while it was completely covered with mercury. Then, by lowering F, the space in D was left under greatly reduced pressure. This caused such a difference in pressure between the upper and lower surfaces of the cheese that the disk was held firmly against the plaster bed, and the surrounding mercury was unable to float it. Preliminary experiments showed that no mercury crept between the disk and the plaster, and that the plaster did not become clogged with mercury or cheese. After partial vacuum had been produced in D a few moments elapsed before the gas retained in the plaster came to equilibrium. When this was reached the mercury was carefully withdrawn from the top of the disk of cheese until the surface was exposed. The mercury left at the side prevented entrance of gas there, so that the only path between the chambers A and D by which gas could enter D was through the cheese.

The disks of cheese used were about 1 cm. in diameter and 2 to 2.5 mm. thick. They were taken from sound portions of freshly cut cheese by means of a cork borer, and carefully sectioned with a sharp razor. Every precaution was used in cutting and handling to prevent distortion and breaking of the texture. In one case the exposed surface was that of an eye. The gas whose diffusion it was desired to study was flooded into the chamber A. With both air and carbon dioxid there was apparently no diffusion during an hour, even though the pressure in D was reduced as much as possible. Longer experiments were not practicable, because a continuous watch had to be kept to see that no bubble of air entered through the rubber connecting tube between D and F and altered the volume in D. With a trap to prevent such a source of error the same impermeability for air was observed during an experiment lasting several days.

This result was so remarkable that it was tested further in the following manner: Instead of the parts E, D, F (fig. 4), a glass tube led from B to a mercury pump. With the cheese slab C covered with mercury the pump was operated till the lowest vacuum which could be obtained was reached. By reason of the gas being given off by the cheese, this was of course not so high a vacuum as the pump can produce. When the vacuum was considered sufficient the pump was allowed to rest in order to discover leakage, and, if there were none, to allow the residual gas to distribute itself so that a reliable reading on the McLeod gauge could be made. Then the mercury was carefully withdrawn from the top of the cheese, leaving its upper surface exposed. Entrance of gas could now be detected by the McLeod gauge. An experiment is given in detail below:

[Disk of cheese 7 mm. diameter, 2.5 mm. thick, taken 10.50 a. m., Dec. 19, 1911, 15 mm. from the nearest rind.]

	Time of reading.	Pressure.
	a. m.	*Mm.*
Apparatus exhausted, and, with cheese covered with mercury, pump pressure at	11.14	0.075
Pump resting	11.25	.140
Do	11.30	.150
Increase in pressure assumed to be due to gas evolved from cheese.		
After 7 minutes pumping	11.37	.070
Cheese exposed to air	11.40	.070
	p. m.	
Do	12.15	.150
Do	1.15	.270
Do	1.50	.320
Do	2.15	.350
After 15 minutes pumping	2.30	.025
Cheese exposed to CO_2	3.10	.060
Do	3.30	.090
After 5 minutes pumping	3.35	.025
Cheese exposed to H_2	4.10	.050
Do	4.30	.065
After 15 minutes pumping	4.45	.010
	a. m.	
Cheese left overnight exposed to air	9.30	.430

When the disk of cheese and the mercury were removed air entered rapidly, showing that the plaster had not become plugged. Furthermore, there was no evidence of mercury having crept between the cheese and the plaster. It is not claimed that all the above listed readings on the McLeod are very accurate, since the readings were sometimes made before equilibrium was obtained. All that was desired was the order of magnitude. Since the variation in temperature during the experiment was only between the extremes 17° C. and 19° C. and since the volume of the pump, gauge, and diffusion apparatus was found to be 159 c. c., we may calculate from pressures the approximate amount of gas which had apparently diffused through the cheese. This amounted to about 0.09 c. c. during the first 5 hours and 0.09 c. c. during the last 17 hours.

Allowing nothing for possible small leaks, which were difficult to avoid in the delicate manipulations required, the observed volume of gas indicates a very remarkable impermeability. Practically the same result was obtained with a disk of Cheddar cheese and other samples of Swiss cheese.

The question at once arises, How to explain the evolution of carbon dioxid which there is every reason to suppose does diffuse from cheese? Van Slyke and Hart[17] found that a normal Cheddar cheese evolved during 32 weeks 15.099 grams of carbon dioxid. Since they took care to exclude surface growths of molds, it seems highly improbable that this amount of carbon dioxid could have come to any great extent from the surface layers alone. It must have diffused from the interior of the cheese into the surrounding bell jar.

The following explanation will doubtless be found reasonable: Becquerel[4] found that when the tegument of peas was mounted at the end of a barometer tube, and a partial vacuum of 5 to 10 mm. obtained upon the one side, with atmospheric pressure on the other, the tegument was impermeable to gas when dry, although permeable when moist. In so far as the tegument of peas and a disk of cheese are both colloidal they may be compared. In the present experiments the disks of cheese dried considerably both from exposure to gases of low vapor content on the one side and the moisture free vacuum on the other. By analogy with Becquerel's experiments one would expect to find the dry cheese more or less impermeable. Reference to the experiment detailed on page 21 will indeed show that the permeability decreased as the time of the experiment increased, or, in other terms, as the cheese became drier. Furthermore, in an experiment in which the exposed surface of the cheese was kept exposed to carbon dioxid, which was saturated with vapor, 1.04 c. c. of gas was found to have passed through in 5 hours; ten times as much as in the experiment with drying cheese.

It therefore seems probable that the permeability of cheese to gases is due to the diffusion of dissolved gases, and that as the free solvent becomes more and more attenuated the gas is more and more unable to find its way through the gel.

Since in Emmental cheese a more or less dry rind is produced, it seems probable that little air can diffuse into the cheese. And from the fact that in the manufacture of Cheddar a less dry rind as well as a more open texture is produced, it seems probable that escape of carbon dioxid more easily occurs in this type than in the Swiss type of cheese.

It must be remembered, however, that the above experiments only cover a very limited time, and that, even were the permeability as low as the experiments seem to show, there is still the possibility that nitrogen may make its way slowly through the gel during the long period of ripening. Possibly more extensive investigation would reveal that the larger percentages of nitrogen found in the eyes of some cheeses are proportional to the age of the cheeses. Nevertheless this penetration can only take place slowly.

The fact that penetration of air is so slow, together with the avidity with which oxygen is absorbed, only tends to emphasize the completeness of the anaerobiosis in the interior of the cheese, a condition which Troili-Peterson[16] found necessary for the best development of the propionic bacteria.

These experiments on the permeability of cheese to gases make it evident that in pumping the gases from plugs of cheese we should expect the gas to be slowly evolved. Such was, indeed, found to be the case. The reason for this was not fully appreciated at the time the pumpings were made, and it is very doubtful if all the occluded gas was completely exhausted even after 20 hours exposure to high vacuum. Reference to the experiment with plugs of cheese kept 6 days in vacuo (p. 15) reveals the interesting fact that the amount of gas evolved per gram of cheese was dependent more upon the state of the vacuum than upon time. This is illustrated in the following statement, in which the figures represent cubic centimeters of gas evolved per gram of cheese per hour:

	1	2
First 18 hours	0.0087	0.0042
Succeeding 6 days	.0015	.0014
Last 18 hours	.0033	.0066

During the middle period, of course, the tubes were sealed, and the evolved gas increased the pressure. Evidently, then, the higher the vacuum to which the sample was subjected the more rapidly was the gas evolved, indicating that a considerable proportion of the gas was dissolved or occluded gas rather than that formed during the time of the experiment.

It may also be true that there is loose combination of carbon dioxid with inorganic salts, or with calcium and amino bodies, as in the carbo-amino reaction, and that the stability of these compounds is a function of the imposed pressure.

NITROGEN DISSOLVED IN CURD.

Let us now consider how much of the nitrogen found in the eyes is attributable to nitrogen occluded in the original curd.

One would expect the curd to be well aerated by the vigorous stirring it gets during the process of manufacture. Marshall [14] has shown that aerated milk contains considerable quantities of nitrogen, but, unfortunately for the purposes desired, his data are only expressed in percentage composition and not very definitely in cubic centimeters of gas per cubic centimeter of milk.

A rough approximation of the amount of nitrogen occluded in the curd was obtained in the following way: A liter of milk was treated as in the process of making Swiss cheese. When the curd had reached the stage when it was suitable to hoop, the greater part of the whey was decanted, and then the residual whey and curd were poured carefully into the glass cylinder A, figure 5 (inverted). As the curd settled, the overlying whey was drawn off and more of the mixture poured in. This was repeated until the tube was filled with curd grains completely surrounded by whey. The rubber stopper was then forced in. The tube was next inverted to the position shown in the figure, and the mercury seal stopcock B was opened to relieve the pressure. The rubber stopper was then forced farther in, and the whey displaced by it escaped into C. By covering the stoppered end of the tube with rubber-rosin cement and keeping it under mercury, it was made perfectly gas tight. The cock B was then closed, and, after the surplus whey in C had been drained out, the apparatus was connected to the vacuum pump in the usual way.

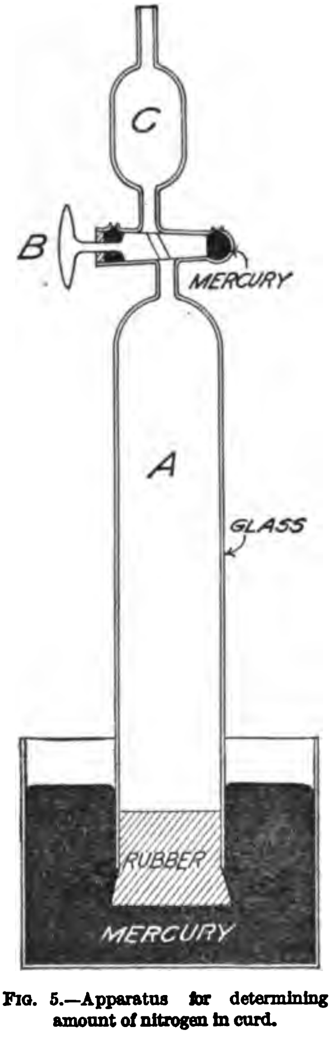

FIG. 5.—Apparatus for determining amount of nitrogen in curd.

When the pump and chamber C were completely exhausted, the cock B was opened. It was found that the gas expanding in A drove the whey almost completely up through the interstices of the curd and into C.

An interesting point was observed. Comparatively little of the gas came from the whey, while the major portion came from the curd particles. Since a separation of whey and curd was accomplished, it could not have been true that the gas evolved from the curd particles originated in the whey, using curd particles as nuclei for the formation of bubbles. Furthermore, there was comparatively little frothing of the whey in C, most of the gas collected having bubbled through C from A. Examination of curd particles will show why this is so; for they have adhering to them minute bubbles, apparently froth taken up during the stirring. It is quite evident that the column of whey in C through which the gas had to make its way prevented a very complete exhaustion. Since the pumping was continued several hours and the tube then allowed to stand overnight before the final pumping, this error was reduced to some extent. If occasion arises to repeat these experiments this error will be avoided.

By the method described, 1.35 c. c. of gas was collected in one instance and 0.86 c. c. in another. Of this, there was 0.58 c. c. of nitrogen in one case and 0.39 c. c. in the other; average, 0.5 c. c. The curd was roughly estimated to represent 20 grams of cheese. Consequently there would be approximately 2.5 c. c. of nitrogen per 100 grams of cheese. How this nitrogen would partition itself between the body of the cheese and an eye is a question whose solution would be mere guesswork without further data.

While the 2.5 c. c. per 100 grams of cheese is a mere approximation, and a figure which would vary not only with the extent to which the curd is stirred, but also with the form of the curd particles and their ability to absorb foam, nevertheless it is sufficiently accurate to show that a large part of the free nitrogen found in cheese comes from occluded air.

DOES NITROGEN ORIGINATE IN SITU?

The question of whether any of the nitrogen found in the eyes is set free in situ is a difficult one to answer, and one which can not be definitely answered without further research. From the following considerations, however, it is highly probable that it is not produced during the course of that reaction which furnishes the gas to distend the eyes. In those experiments in which samples from a cheese at the period of its maximum eye formation were held in vacuo, the nitrogen in the evolved gas steadily and rapidly declined in percentage, finally reaching almost nothing. This indicates that the nitrogen collected was simply that dissolved in the cheese, and as this was removed there was no evolution of free nitrogen to take its place, such as occurred in the case of the carbon dioxid.

RELATION BETWEEN CARBON DIOXID AND VOLATILE ACIDS.

The results of the whole investigation show clearly that the only gas which plays an important rôle in the formation of normal eyes is carbon dioxid. This is in entire harmony with the assumption which has heretofore been accepted as a fact by various authors.

It remains to be seen whether there is any quantitative relation between the amount of carbon dioxid evolved and that called for by the process to which Von Freudenreich and Jensen ascribe the formation of eyes.

A study of the volatile fatty acids of Emmental cheese by Jensen[12] disclosed the fact that they are chiefly propionic and acetic, and that often the ratio of these approximates 2:1.

Fitz[7] had previously shown that certain bacteria are capable of producing this ratio of propionic and acetic acids from lactic acid, and he ascribed to their action the equation:

$$\underset{\text{lactic}}{3C_3H_6O_3}=\underset{\text{propionic}}{2C_3H_6O_2}+\underset{\text{acetic}}{C_2H_4O_2}+CO_2+H_2O$$

Subsequently Von Freudenreich and Jensen[8] isolated from Emmental cheese an organism which did ferment lactates according to the above equation of Fitz, and whose introduction into cheese was followed by an eye formation of which it was thought to be the cause.

The conclusion seems evident that here is an organism to whose action may be attributed the formation of normal eyes.

The evidence is undoubtedly the clearest that has yet been presented. There are, however, one or two points which will bear inspection before the theory can be accepted as a full explanation.

According to the equation of Fitz three molecules of volatile fatty acids are accompanied by the liberation of one molecule of carbon dioxid. Consequently it can be shown that a titer of 1 c. c. of tenth-normal alkali for these volatile fatty acids should indicate the liberation of 0.74 c. c. of carbon dioxid (N. T. P.). If, then, it is found that the volatile acids from 100 grams of cheese neutralize 100 c. c. of tenth-normal alkali, and it is assumed that these acids are acetic and propionic in the ratio in which they occur in Fitz's equation, we would have liberated 74 c. c. of carbon dioxid per 100 grams of cheese.

This amount of gas is considerably more than is required to fill the eyes, but the question remains how much is to be found in the body of the cheese itself.

Reference to the experiments described on page 15 shows that at an age of 55 days 37.2 c. c. of carbon dioxid per 100 grams of cheese were collected after the cheese has been held in vacuo one week. At the time of the experiment it was thought that this gas was produced during that week. After the study which shows how impermeable cheese is, this view had to be modified, for, even after considerable pumping, an appreciable quantity of gas must have remained and appeared as "evolved" gas at the end of the week. In order to make a better estimation of the dissolved gas, plugs of this same cheese (at an age of 4 months) were sliced into thin disks to facilitate the removal of dissolved gas, and introduced into a tube. They were sealed in with the usual rubber stopper and rubber-rosin cement, and the tube joined to the mercury pump. After evacuating the pump the connecting cock was opened and the disks of cheese evacuated. The air surrounding them in the tube was of course pumped out too. The total gas thus collected after 5 hours continuous pumping contained 17.05 c. c. of carbon dioxid. The weight of cheese was 42 grams. Hence, there were collected 40.6 c. c. of carbon dioxid per 100 grams of cheese (19 hours later 0.9 c. c. of carbon dioxid was collected, or 2.1 c. c. per 100 grams of cheese).

A duplicate determination gave 46.2 c. c. of carbon dioxid per 100 grams of cheese (with an additional 1.03 c. c. per 100 grams after 19 hours). The average for the first 5 hours' pumping was 43.4 c. c. of carbon dioxid per 100 grams of cheese, and this we may fairly consider the quantity occluded at the time the plugs were taken. At the same age (4 months) the volatile fatty acids corresponded to 40.9 c. c. of tenth-normal alkali per 100 grams of cheese.

Similarly, duplicate determinations of dissolved carbon dioxid and volatile acids in an excellent imported cheese (No. *i*) gave the following data: Carbon dioxid per 100 grams, 67.8 c. c. and 54.8 c. c., average 61.3 c. c. Total volatile fatty acids in cubic centimeters of tenth-normal alkali per 100 grams 95.1 and 97.7, average 96.4.

Assuming that all the volatile fatty acids were produced in strict accordance with the equation of Fitz, the amount of these acids in the first cheese indicates that there had been liberated 30.6 c. c. of carbon dioxid against 43.4 c. c. found occluded; and in the second cheese the liberation of 71.3 c. c. of carbon dioxid against 61.3 c. c. found occluded. There is a somewhat striking apparent relationship in this data, and the averages, 51.0 c. c. calculated, against 52.3 c. c. found, are in such close agreement that they are tempting. A little consideration will show, however, that this agreement may be only accidental. At the time these analyses were made each of the cheeses had probably reached a state of little activity. The volatile acids represent almost entirely the total amount produced in the interior from which the samples for analyses were taken; while, if we are to accept the results on Cheddar cheese by Van Slyke and Hart as at all applicable to Emmental, it is certain that a considerable quantity of carbon dioxid must have escaped in the months since manufacture. Furthermore, although the actual volume of the eyes represents but a small portion of the gas in a given volume of cheese, the normal volume of this gas in the eyes leaps into considerable significance when it is remembered that it must have been under considerable pressure. That it is under pressure was made evident in some cases by its vigorous escape when using the puncturing apparatus for its collection.

Unfortunately long delay in obtaining apparatus suitable for a study of the gas escaping from cheese, as was done by Van Slyke and Hart for Cheddar, have made it impossible to present any data on this point. As before mentioned, the data on carbon dioxid evolved from plugs of cheeses taken at the height of their gaseous fermentation and kept in vacuo a week is complicated by the fact that there was probably a slow yielding of dissolved gas from the solid plugs as well as the normal production of gas. Two other experiments, however, indicate to what extent carbon dioxid was being formed during this period of maximum fermentation.

Portions of cheese W 2 from regions without eyes were carefully selected and sealed up in a tube as described on page 14. The eye membranes were carefully removed from a large number of eyes and similarly treated. The tubes were simultaneously exhausted with a Boltwood pump for several hours. Since in these cases the cheese was in a more finely divided state, it is reasonable to assume that predissolved gas was pretty thoroughly removed. After exhaustion, the tubes were sealed off in a blowpipe flame and held at 25° C. for seven days. At the end of this period the gas was collected:

34 grams eye membranes gave 14.95 c. c. of gas, 99.3 per cent of carbon dioxid, or 44 c. c. per 100 grams.

36 grams from regions without eyes gave 10.06 c. c. of gas, 98.2 per cent of carbon dioxid, or 28 c. c. per 100 grams.

From this one pair of experiments it is not advisable to claim confidently that the eye surfaces always produce the much larger quantity of carbon dioxid, although this is plainly evident in the above case. The significant fact is that such a large quantity was produced by each region in the period of only one week. Of course it may be claimed that although the division of the cheese was done in a dust-free room and with sterile instruments, and the cheese introduced into sterile tubes, yet the long manipulation admitted a heavy reinoculation by bacteria, and that these produced a renewed evolution of carbon dioxid. Such an argument can not be completely refuted, but the probability of a heavy enough infection is small. The most likely source of carbon dioxid producing infection was by molds, but these could not have grown in the complete anaerobic condition in which the cheese quickly found itself.

The following experiment serves to confirm the last. Into a sterilized combustion tube were quickly slipped plugs of cheese taken with sterile instruments. Each end of the tube was guarded with cotton plugs. Carbon dioxid free air was then passed through, and the carbon dioxid evolved from the cheese absorbed in the customary train with all due precautions for exact estimation of carbon dioxid. In the case of this experiment we would expect a higher amount of carbon dioxid, since there would be collected not only the carbon dioxid produced, but a large portion of the predissolved carbon dioxid. Such was found to be the case.

One hundred and five grams in plugs taken from cheese W 1 when at the height of its fermentation gave:

First 24 hours, 81.6 c. c. of carbon dioxid.
Second 24 hours, 66.7 c. c. of carbon dioxid.
Third 24 hours, 44.5 c. c. of carbon dioxid.
Fourth 24 hours, 63.7 c. c. of carbon dioxid.

The increase on the fourth day was thought to be due possibly to growth of molds with which Van Slyke and Hart found difficulty in their work on Cheddar cheese. The experiment was therefore discontinued, although no growth was visible.

A final word must be urged against the too liberal use of the equation of Fitz. As a terse representation of the probable relation of the end products the equation has a legitimate use. As a comprehensive portraiture it is colored with presumption. The literature of fermentation is littered with equations, two or three members of which are known to stand in certain quantitative relationships, while the other members are given values which fit. This stoichiometrical adjusting is particularly true of the gaseous products. One has only to review the literature on the gas production of *B. coli* to assure himself of the fact.

While Von Freudenreich and Jensen's use of the Fitz equation has been interpreted quite rigidly in the preceding pages, this was done simply as a test. From this basis alone one can not reasonably jump to a final conclusion; but it must be remembered that the liberal use made of the Fitz equation was generous to the theory of Von Freudenreich and Jensen in that all the volatile fatty acids, as determined by Jensen's method, were assumed to have been produced in accordance with this equation.

From a comprehensive view of the matter it appears to be quite evident that the theory of Von Freudenreich and Jensen is not capable of accounting for all the carbon dioxid produced. Indeed, it is not necessary nor expected that it should, but we have reached a point where it has become advisable to distinguish between a primary and a secondary cause of eye formation, and to at least define clearly what we mean when we attribute to any organism or to any reaction the function of forming eyes.

Suppose that the propionic bacteria are active, but that they are never sufficiently localized to concentrate carbon dioxid rapidly enough at one point to produce an eye. In this case the gas would be more or less evenly producėd throughout the body of the cheese. Now this state of more or less complete saturation of the body with carbon dioxid is exactly the condition necessary for the most advantageous eye formation by any other reaction which may follow, else the gas evolved at a point would be largely absorbed and its inflating energy dissipated. Of course it can be said that this saturation proceeds from the point where the eye is formed, and that the delay observed before an eye commences to grow represents the time necessary to effect this saturation.

This, however, is merely presenting the other horn of a dilemma from which escape is possible only when the localization of the propionic bacteria is conclusively demonstrated. Gorini[9] has contended that the localization of colonies may often be of as great importance as their isolation; and it is interesting to note that he found no correlation between the colonies which stained on his sections of Grana cheese and the gas bubbles.

If, then, we distinguish between a "saturating" gas production and an "inflating" gas production, we will have at least defined a possibility which must be squarely met, and a hypothesis which may lead to a differentiation between a primary and a secondary cause of eye growth.

The favorable results obtained with cheese inoculated with propionic bacteria indicate that they may play an important rôle. But is this rôle primary or secondary? Is it a strictly localized action or is it simply the provision of that saturation without which some primary and strictly localized reaction would be without avail? The same question arises in the case of the glycerin-fermenting bacteria to which Troili-Petersson[16] has ascribed an important rôle in the holing of Swedish cheeses. In fact experimental cheesemaking of the past, though not so thoroughly controlled as in the experiments of Troili-Petersson and those of Von Freudenreich and Jensen, bear evidence that any one of a number of gas-producing bacteria may provide the saturation, not to mention those reactions which Van Slyke and Hart[17] have proposed as contributing to the carbon dioxid in Cheddar cheese. On the other hand, any one of these may be the primary "inflator" and the other the secondary "saturator."

In this connection it may be of interest to note a peculiar phenomenon met with in some experimental cheeses. A number of these made with "artificial" rennet by Mr. Doane were reported in their early stages to have begun a normal eye formation. Seldom, however, did this beginning develop into a normal holing. These cheeses were of small size, and, since it is known that small-sized cheeses for some reason not yet clearly defined seldom develop large eyes, the failure in these cases may on general principles be vaguely attributed to size. However that may be, it was found upon pumping out the dissolved gas that the amount was low. The three cheeses examined were 39–45, 39–11–2, and 46–4–1. (See Table 2, p. 12.)

It is well known from the work of Jensen and others that the bacteria found in "natural" rennet are often distinct from those found in "artificial" rennet. Since the cheeses under discussion were made with the latter, is it not possible that the reaction which started the eye formation was rendered inadequate because the gas-producing propionic bacteria, which might have saturated the cheese with carbon dioxid, were absent? That the observed holes were truly the beginnings of normal eyes, and were not a pinhole formation resulting from an initial gaseous fermentation of sugar, is evinced by the fact that hydrogen was absent.

Exhaustive research alone can unravel this tangle; but it is hoped that the present investigation has provided both a clearer definition of the problem and a sound basis of fact.

SUMMARY.

1. The gases of normal "eyes" in Emmental cheese are exclusively carbon dioxid and nitrogen, and of these only the carbon dioxid is of significance.
2. The nitrogen accompanying the carbon dioxid in normal eyes is that of air originally occluded in the curd at the time of manufacture.
3. There sometimes occurs during the initial fermentation an evolution of gas characterized by the presence of hydrogen. This is believed to be due to the gaseous fermentation of sugar.
4. The hydrogen from such an initial fermentation may sometimes linger to contaminate the gas of normal eyes.
5. The two fermentations are distinct and are characterized by their gaseous products. The one is detrimental, the other that demanded of a good Emmental cheese.
6. High oxygen-absorbing power combined with low permeability of the cheese to air render the interior thoroughly anaerobic, and consequently favorable to the growth of anaerobic bacteria.
7. A comparison between the amount of carbon dioxid evolved and the total volatile fatty acids shows that the activity of the propionic bacteria of Von Freudenreich and Jensen is not sufficient to account for all the carbon dioxid found.
8. It was found that cheese is capable of retaining a very large amount of carbon dioxid.
9. The possibility is suggested that there are two phases in the formation of normal eyes, a saturation of the body with carbon dioxid, and an inflation of eyes; and the bearing of this hypothesis on the production of gas by a specific cause is discussed.

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BUREAU OF ANIMAL INDUSTRY.—BULLETIN 152.

A. D. MELVIN, CHIEF OF BUREAU.

STUDIES ON THE BIOLOGY OF THE TEXAS-FEVER TICK.

(SUPPLEMENTARY REPORT.)

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Animal Industry,
Washington, D. C., April 25, 1912.

Sir: In Bulletin 130 of this bureau there were reported the results of one year's investigations of the biology of the Texas-fever tick which were carried on during 1907 and 1908 at Auburn, Ala., by cooperation between the Alabama Polytechnic Institute and this bureau. The work was continued for another year, and I have the honor to transmit herewith a supplementary report by Dr. H. W. Graybill and Mr. W. M. Lewallen, giving the results of the second year's experiments (1908–9). As this information has a bearing on the cooperative work now being carried on by the bureau and the authorities of certain States for the eradication of the cattle tick, I recommend its publication as a bulletin of this bureau.

Respectfully,

A. D. Melvin,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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STUDIES ON THE BIOLOGY OF THE TEXAS-FEVER TICK.

(SUPPLEMENTARY REPORT.)

INTRODUCTION.

During 1907–8 the Zoological Division of the Bureau of Animal Industry conducted a year's experiments on the life history of the Texas-fever tick at Auburn, Ala., in cooperation with the veterinary department of the Alabama Polytechnic Institute. The results obtained during the course of those investigations have been published in Bulletin 130 of the Bureau of Animal Industry. The work was continued for another year (1908–9) along the same but somewhat less extensive lines. Mr. W. M. Lewallen, who assisted in the first year's work, had charge of the experiments during the second year.

The second year's work was undertaken for the purpose of obtaining additional data on the nonparasitic periods in the life history of the tick, and to determine what variations might take place in the duration of these as a result of yearly variations in weather conditions.

METHODS OF STUDY.

The methods of study employed were the same as those used the first year. The indoor experiments were conducted by the use of incubation tubes, and these were checked by outdoor experiments conducted in field plots representing natural conditions. The incubation tubes used were the vertical type provided with a glass tube inserted into the bottom for the purpose of supplying the sand with moisture, shown in figure 1, Bulletin 130, Bureau of Animal Industry. The field plots were the same as those used in the first year's work (fig. 3, Bulletin 130), being 2 feet square. They were protected from the intrusion of small animals by means of a wire-netting fence.

In the indoor experiments the ticks were handled the same as during the first year. Four engorged ticks were collected at the beginning of each month, and each was placed in a dish by itself, where it remained until oviposition was completed. At the end of every 24 hours the eggs were removed from each tick, counted, and placed in an incubation tube marked with the number assigned the tick and the date the eggs were removed. The dates when the eggs in each tube began and completed hatching, and when the first and last larvæ died, were recorded, and finally the per cent of eggs that hatched was determined. The indoor experiments were conducted in an unheated room, the windows of which were constantly open.

In the outdoor experiments two sets of plots were run, one located in a place shaded a part of the day and the other in the sun. In each plot 10 engorged females were placed.

PREOVIPOSITION PERIOD.

The minimum preoviposition period noted was 2 days, which occurred in the case of ticks collected in August. Ticks collected in August the first year had a minimum period of 2 days, but the minimum for the year (1 day) was observed in the case of a tick collected in April. The maximum period (29 days) was exhibited by ticks collected December 2, and the maximum for the first year (98 days) was observed in the case of a tick collected November 30.

From the table (last column) it will be noted that the average preoviposition periods increase month by month from the minimum to the maximum, and then decrease again to the minimum. A similar increase and decrease were also shown in the case of averages for the first year's experiments in the horizontal tubes, but in the case of the ticks used for the vertical-tube experiments the averages for April and June were greater than for March.

Preoviposition period—Range and average length of periods.

Date ticks were collected.	Number of ticks.	Range of preoviposition periods.	Average of preoviposition periods.	Date ticks were collected.	Number of ticks.	Range of preoviposition periods.	Average of preoviposition periods.
1908.		*Days.*	*Days.*	1909.		*Days.*	*Days.*
August 5	4	2 to 4	3	January 1	4	22 to 24	23
September 1	4	3 to 5	4	February 4	4	18 to 20	19.3
October 1	4	5 to 11	7.8	March 1	4	9 to 16	11.8
November 2	4	7 to 9	8.3	April 2	4	9 to 10	9.8
December 2	4	17 to 29	25.5	July 2	4	3	3

OVIPOSITION PERIOD.

The longest oviposition period noted was 82 days, observed in the case of a tick which began ovipositing in January. A tick in the first year's experiments which began to lay eggs in January had an oviposition period of 91 days, but the longest period was exhibited by a tick which began ovipositing in November and continued to lay eggs for 152 days. The second year the shortest period (7 days), as well as the longest, occurred in January. The tick giving this period, however, deposited only 305 eggs, an exceptionally small number. The shortest period the first year was 3 days, and this occurred in June. The average oviposition periods for the first year increased month by month from a minimum in June to a maximum in November, and gradually decreased again in the succeeding months. During the second year the same tendency was shown, the periods increasing from a minimum in August to a maximum in November, and then, following a sudden decrease for December, there was an increase for January and February, after which the decrease was regular for the remaining months.

Oviposition period—Range and average length of periods.

Month oviposition began.	Number of ticks.	Range of oviposition periods.	Average of oviposition periods.	Month oviposition began.	Number of ticks.	Range of oviposition periods.	Average of oviposition periods.
1908.		*Days.*	*Days.*	1909.		*Days.*	*Days.*
August	4	13 to 15	14.3	February	4	37 to 59	46.8
September	4	9 to 18	14.8	March	4	22 to 42	33.3
October	4	13 to 35	25.3	April	4	26 to 32	29
November	4	56 to 63	59.5	May	4	19 to 27	23.8
December	4	30 to 42	34.5	June	4	11 to 19	15.8
				July	4	12 to 17	14.8
1909.							
January	4	7 to 82	45.8				

INCUBATION PERIOD.

The range of the incubation periods of the lots of eggs laid by each tick is given in the table in the Appendix. The range of the period for the second year was 18 to 176 days, as compared with 19 to 188 days for the first year. In the table below only the periods from the time the eggs were deposited until the first eggs hatched in each lot have been used, and these are referred to for convenience as the minimum incubation periods. The periods to the hatching of the last eggs in each lot have been included in the table in the Appendix. The longest minimum incubation period for both the first and the second year occurred in the case of lots of eggs deposited during the month of October, being 173 days for the second year and 180 days for the first year. The shortest period for the second year was 18 days and was observed in the case of lots of eggs deposited during the month of June, while the lots deposited during the same month of the first year gave a minimum period of 22 days. The shortest period for the first year (19 days) was furnished by lots of eggs deposited during the months of July and August.

By comparing the averages in the table below it will be observed that they increase from August to October and decrease for the remaining months, except in the case of the average for July, which shows a slight increase. In case of the averages for the first year it is noted that they increase for the months of August to October and decrease for the remaining months without interruption.

Minimum incubation period—Range and average length of periods.

Month eggs deposited.	Number of lots.	Range of periods.	Average of periods.	Month eggs deposited.	Number of lots.	Range of periods.	Average of periods.
1908.		*Days.*	*Days.*	1909.		*Days.*	*Days.*
August	52	20 to 30	23.1	February	48	82 to 107	95.5
September	49	32 to 70	44.8	March	170	58 to 90	71.5
October	49	141 to 173	158.7	April	141	38 to 65	47.5
November	66	151 to 171	157.5	May	90	26 to 39	30.6
December	21	139 to 158	150.3	June	47	18 to 26	22.9
				July	51	22 to 27	24.5
1909.							
January	70	103 to 141	121.6				

HATCHING PERIOD.

The maximum hatching period for the second year was 52 days and for the first year 49 days, and in the case of both years this period belonged to a tick whose eggs began to hatch during the month of October. The shortest hatching period for the second year was 6 days and occurred in the case of a tick whose eggs began to hatch in May, while for the first year the minimum period for the same month was 9 days. The shortest period during the first year (4 days) fell to the month of July. It is noted by referring to the averages in the table below that those for October and February are the same, and for the remaining months, with the exception of the break shown by May, there is a decrease, month by month, of the averages. In the first year's work the averages increased from that for July to the maximum, which is for the month of October, and decreased for the remaining months, except for a slight increase for the month of June.

Hatching period—Range and average length of periods.

Month hatching began.	Number of ticks.	Range of hatching periods.	Average of hatching periods.	Month hatching began.	Number of ticks.	Range of hatching periods.	Average of hatching periods.
1908.		*Days.*	*Days.*	1909.		*Days.*	*Days.*
August	4	17 to 27	21.5	March	2	33 to 46	39.5
October	4	47 to 52	50	April	4	18 to 21	19.3
				May	20	6 to 21	13.8
1909.				June	4	12 to 18	16
February	1	50	50	July	8	11 to 21	14.5

LONGEVITY PERIOD.

The longest and shortest longevity periods obtained for the lots of larvæ belonging to each tick are given in the table in the Appendix. The time to the death of the first larvæ in each lot is referred to in the table below as the minimum longevity period and that to the death of the last larvæ as the maximum longevity period. The longest maximum longevity period for the second year was 249 days, as compared with 234 days for the first year, and both occurred in the case of lots of eggs which began to hatch during the month of October. In referring to the averages it will be noted that there is no regular increase and decrease to and from the maximum, and the same was noted in the case of the first year's experiments. This is no doubt due to the fact that temperature, while it plays some part, is not a controlling factor in the longevity of larvæ as it is in the case of the preoviposition, oviposition, hatching, and incubation periods. The range of the averages for the months of August to November of the second year is 104.5 to 213.7 days, whereas the range for the same months of the first year is 56.2 to 167.4 days. The range of the averages for the rest of the months of the second year is 63.3 to 77.6 days, as compared with a range of 38.6 to 73.2 for the remaining months of the first year.

Longevity period.—Range of maximum and minimum longevity and average of maximum longevity.

Month lots began to hatch.	Number of lots.	Range of minimum longevity periods.	Range of maximum longevity periods.	Average of maximum longevity periods.	Month lots began to hatch.	Number of lots.	Range of minimum longevity periods.	Range of maximum longevity periods.	Average of maximum longevity periods.
1908.		*Days.*	*Days.*	*Days.*	1909.		*Days.*	*Days.*	*Days.*
August......	6	16 to 36	99 to 192	121.8	April.......	72	6 to 60	31 to 110	75.3
September..	46	6 to 62	50 to 218	104.5	May........	355	8 to 87	14 to 119	77.6
October.....	31	13 to 155	80 to 240	213.7	June........	180	7 to 85	25 to 139	66.1
November..	18	51 to 146	58 to 223	149.9	July........	56	9 to 48	9 to 106	63.3
					August.....	42	7 to 47	31 to 118	64.6
1909.									
March.......	30	10 to 42	10 to 112	71.6					

ENTIRE TIME OF NONPARASITIC DEVELOPMENT.

The entire time for each individual tick and its progeny, i. e., the time from dropping to the death of all the larvæ, is given in the table in the Appendix. The longest entire time during the second year (297 days) was obtained in the case of ticks collected September 1, while the longest period for the first year (288 days) occurred in the case of ticks collected October 1. The shortest period for the second year was 96 days and for the first year 79 days, and both occurred in the case of ticks collected the first part of June. The averages for the first year increase month by month from June to a maximum for October, and then decrease for the remaining months, except that the averages for February and March are the same. The averages for the second year, given in the last column of the table below, do not increase to and decrease from the maximum without deviations, as do those for the first year.

Entire time of nonparasitic development.

Date engorged females were collected.	Number of engorged females.	Range of entire-time periods.	Average of periods.	Date engorged females were collected.	Number of engorged females.	Range of entire-time periods.	Average of periods.
1908.		*Days.*	*Days.*	1909.		*Days.*	*Days.*
August 5	4	143 to 254	206.5	January 1	4	202 to 253	235
September 1	4	258 to 297	280	February 4	4	204 to 230	218.5
October 1	3	271 to 280	279.3	March 1	4	185 to 207	198.3
November 2	4	274 to 288	282	April 2	4	139 to 164	154
December 2	4	257 to 268	264.8	May 1 (?)	4	140 to 185	156.5
				June 2 (?)	4	96 to 127	117
				July 2	4	110 to 149	129.5

NUMBER OF EGGS LAID AND PERCENTAGE HATCHED.

During the second year the minimum number of eggs laid by a tick was 305 and the maximum 4,492. The average number of eggs laid by the various lots of ticks ranged from 1,885 to 4,262. The lowest percentage of eggs hatched was 3 per cent and the highest 98 per cent. The percentage of eggs hatched in the case of ticks collected during December, January, and February ranged from 3 to 60 per cent. For the first year the minimum number of eggs laid was 357 and the maximum number was 5,105, and the averages ranged from 1,811 to 4,089. The percentage of eggs hatched ranged from 0 to 98 per cent.

Egg laying and hatching—Total and average number of eggs laid and per cent hatched.

Date collected.	Number of ticks.	Number of eggs deposited.	Average number of eggs.	Per cent of eggs hatched.	Date collected.	Number of ticks.	Number of eggs deposited.	Average number of eggs.	Per cent of eggs hatched.
1908.					1909.				
August 5	4	3,962 to 4,492	4,262	48 to 97	January 1	4	305 to 3,723	2,615	3 to 60
September 1	4	2,797 to 3,654	3,252	92 to 98	February 4	4	1,993 to 2,970	2,568	11 to 41
October 1	4	1,588 to 3,848	2,768	9 to 61	March 1	4	1,380 to 3,361	2,352	61 to 93
November 2	4	2,215 to 3,329	2,975	52 to 71	April 2	4	1,741 to 3,065	2,476	86 to 95
December 2	4	1,496 to 2,201	1,885	11 to 27	May 1[1]	4	3,181 to 4,178	3,674	69 to 93
					June 2[2]	4	1,640 to 3,003	2,180	60 to 97
					July 2	4	2,214 to 3,710	2,948	96 to 98

[1] Ticks were collected May 1 and 2.

[2] Ticks were collected June 2, 3, 4, and 5.

COMPARISON OF RESULTS OF INDOOR AND OUTDOOR EXPERIMENTS.

In the next table the dates when the first eggs hatched and when all the larvæ were dead in each month's experiments, indoors and outdoors, are given for purposes of comparison. These dates are of much practical importance in eradication work when rotation methods are employed, since the dates when the first eggs hatched are those on which ticky cattle placed on tick-free land on dates corresponding to those on which the experiments were begun will be in danger of reinfestation, and the dates on which all larvæ were dead are the dates on which pastures from which all animals have been removed will be free of ticks.

Comparison of records of vertical tubes and field plots, Auburn, Ala., 1908–9.

Vertical tubes.			Field plots.		
Date females were collected.	Date first eggs hatched.	Date all larvæ were dead.	Date females were collected.	Date first eggs hatched.	Date all larvæ were dead.
1908.			1908.		
August 5	Aug. 30	Apr. 16	August 5–6	Aug. 31	Apr. 3
September 1	Oct. 7	June 25	September 1	Nov. 23	May 22
October 1	Feb. 25	July 8	October 1	Apr. 19	June 23
November 2	Apr. 22	Aug. 17	November 2	May 10	Do.
December 2	May 11	Aug. 27			
1909.			1909.		
January 1	May 19	Sept. 11	January 1	May 21	July 30
February 4	May 21	Sept. 22	February 1–4	May 20	Aug. 6
March 1	May 24	Sept. 24	March 1–3	do	Aug. 25
April 2	May 28	Sept. 13	April 2	May 26	Sept. 11
May 1–2	June 10	Nov. 2	May 1–2	June 12	Do.
June 2–5	July 2	Oct. 7	June 2–5	June 28	Oct. 2
July 2	July 28	Nov. 28	July 1–2	July 26	Nov. 13

In comparing the length of time required for the first eggs to hatch in the indoor and outdoor experiments it was found that for all the months except March, April, June, and July the time was longer in the outdoor than in the indoor experiments, the differences ranging from 1 to 53 days, and for the above-mentioned months the time was shorter, the differences ranging from 1 to 4 days. The longer time obtained in the majority of the outdoor experiments may be due in part to unavoidable errors in observation because of the fact that it is frequently difficult to determine with certainty when the first eggs hatch, since they are scattered and some may be hidden from view. In the first year's experiments practically the same results were obtained. For two of the eight months for which comparisons could be made the time was the same in the indoor and outdoor experiments, and for the remaining months the time was longer in the outdoor experiments, the differences ranging from 1 to 22 days.

In view of the fact that in the two years' experiments the time to the hatching of the first eggs was longer in the outdoor experiments than in the corresponding indoor experiments in all except four instances, in which cases the differences were comparatively small, ranging from 1 to 4 days, it seems safe to assume that indoor experiments, if the temperature is maintained near that on the outside, will be safe to follow in practical work, provided a reasonable margin of safety be allowed to cover slight variations that might occur in the direction of a shorter time for hatching.

In the second year's work, for all months the time required for all the larvæ to die was longer in the indoor than in the outdoor experiments, the differences ranging from 2 to 55 days, and the average difference being 28 days. In the first year's experiments similar results were obtained; in all but one case the periods were longer in the indoor than the outdoor experiments, the differences ranging from 5 to 42 days, the average difference being 21 days. It therefore appears that the time obtained indoors, with incubation tubes of the type employed, as a rule will be three to four weeks longer than that occurring under natural conditions. This is what would be expected, since ticks in tubes are not exposed to the wind, and when kept indoors are not subjected to the sun, in consequence of which they will not suffer the loss of body fluids and nourishment that ticks living in the open will. In addition to this, it is likely that the humidity in the tubes as a rule is higher than that of the outside air, which would tend to prolong longevity of the larvæ. It is believed that in using tubes such as were employed, the supply of moisture should not be excessive, the sand simply being kept moist. Unless this is done it is likely that the life of the larvæ may be prolonged far beyond that occurring under natural conditions. Unduly long periods for the death of all larvæ, obtained by using incubation tubes, are safe but uneconomical, requiring the farmer to forego the use of his land longer than is necessary. It is important that the periods be ample, but it is likewise important that they be no more than this, since rotation methods are inconvenient and expensive at best in the majority of instances.

In comparing the time required for all the larvæ to die for corresponding months in the indoor experiments for the two years it was found that for all but one month the time was longer the second year, the differences ranging from 3 to 45 days. The average difference was 25 days. A similar comparison of the outdoor experiments for the two years showed that in every instance the time was longer the second year, the differences ranging from 2 to 36 days. The average difference was 17 days.

APPENDIX.

Individual records of ticks used in experiments.

Number of tick.	Date collected.	Number of eggs deposited.	Preoviposition period.	Oviposition period.	Hatching period.	Incubation period.	Minimum longevity.	Maximum longevity.	Entire time.	Per cent hatched.
	1908.		*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	
1	Aug. 5	4,492	3	15	27	20 to 36	15	116	143	48
2	...do...	3,962	4	13	17	20 to 30	12	218	254	97
3	...do...	4,489	3	15	24	21 to 34	17	141	182	61
4	...do...	4,104	2	14	18	21 to 30	6	207	247	60
5	Sept. 1	3,654	3	16	52	32 to 73	58	249	286	98
6	...do...	3,604	4	18	51	36 to 75	15	237	279	92
7	...do...	2,951	4	9	47	31 to 71	21	222	258	93
8	...do...	2,797	5	16	50	34 to 70	13	249	297	92
9	Oct. 1	1,588	11	13	....	....	....	....	....	....
10	...do...	3,848	5	35	50	141 to 176	10	100	280	19
11	...do...	2,730	7	20	33	151 to 174	10	87	271	9
12	...do...	2,906	8	33	46	146 to 174	7	112	278	61
13	Nov. 2	3,187	7	63	18	151 to 170	11	107	285	52
14	...do...	3,329	9	56	19	152 to 168	6	98	274	57
15	...do...	3,167	8	58	19	151 to 170	14	110	281	59
16	...do...	2,215	9	61	21	143 to 169	18	106	288	71
17	Dec. 2	1,858	28	31	9	114 to 138	18	100	268	27
18	...do...	1,985	28	35	18	103 to 142	8	97	266	17
19	...do...	2,201	17	42	16	116 to 144	19	100	268	15
20	...do...	1,496	29	30	9	115 to 139	8	87	257	11
	1909.									
21	Jan. 1	3,723	24	82	21	61 to 119	16	104	243	60
22	...do...	3,460	24	48	18	73 to 120	16	113	253	18
23	...do...	2,970	22	46	16	94 to 121	21	103	242	17
24	...do...	305	22	7	6	111 to 117	49	64	202	8
25	Feb. 4	2,601	19	49	17	53 to 87	17	98	204	33
26	...do...	2,970	18	42	17	68 to 97	21	114	225	36
27	...do...	2,706	20	59	14	49 to 87	7	111	230	41
28	...do...	1,993	20	37	12	70 to 90	28	106	215	11
29	Mar. 1	2,994	9	41	15	45 to 81	25	116	205	79
30	...do...	1,674	10	28	8	57 to 84	14	107	196	61
31	...do...	3,361	12	42	14	44 to 77	25	97	185	93
32	...do...	1,380	16	22	8	55 to 77	25	119	207	62
33	Apr. 2	2,607	9	26	17	36 to 49	20	106	164	94
34	...do...	3,065	10	32	13	39 to 50	23	95	154	86
35	...do...	1,741	10	27	14	39 to 51	15	101	159	94
36	...do...	2,491	10	31	14	35 to 48	11	81	139	95
37	May 1[1]	4,178	....	27	18	26 to 39	19	118	158	93
38	...do...	4,040	....	25	17	27 to 37	17	96	140	73
39	...do...	3,181	....	24	17	28 to 36	25	100	143	85
40	...do...	3,296	....	19	12	27 to 41	14	139	185	69
41	June 2[2]	2,311	....	19	13	18 to 27	18	80	114	97
42	...do...	3,003	....	11	13	21 to 27	20	95	127	84
43	...do...	1,765	....	15	13	22 to 29	20	62	96	60
44	...do...	1,640	....	18	11	21 to 27	9	84	117	89
45	July 2	3,452	3	15	16	24 to 27	12	118	149	98
46	...do...	3,710	3	17	21	22 to 27	13	94	125	98
47	...do...	2,214	3	12	15	23 to 29	20	81	110	96
48	...do...	2,416	3	15	14	23 to 28	7	106	134	98

[1] Ticks were collected May 1 and 2.

[2] Ticks were collected June 2, 3, 4, and 5.

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U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ANIMAL INDUSTRY.—BULLETIN 153.

A. D. MELVIN, CHIEF OF BUREAU.

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THE ACTION OF ANTHELMINTICS ON PARASITES LOCATED OUTSIDE OF THE ALIMENTARY CANAL.

BY

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AND

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WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1912.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Animal Industry,
Washington, D. C., May 2, 1912.

Sir: I have the honor to transmit herewith, and to recommend for publication as a bulletin of this bureau, a manuscript entitled "The Action of Anthelmintics on Parasites Located Outside of the Alimentary Canal," by Dr. B. H. Ransom, Chief of the Zoological Division, and Mr. Maurice C. Hall, assistant zoologist in the Zoological Division of this bureau.

This paper details the results of some attempted medicinal treatment of sheep for tapeworm disease, and also summarizes our knowledge of the use of anthelmintics against parasites located outside of the intestinal lumen. While the experimental results were negative, the evidence brought together here indicates the need of further work, and this paper is intended to simplify additional work by furnishing a systematic summary of all previous work. It also has immediate practical utility as an aid in judging the claims made for proprietary medicines.

Very respectfully,
A. D. Melvin,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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THE ACTION OF ANTHELMINTICS ON PARASITES LOCATED OUTSIDE OF THE ALIMENTARY CANAL.

INTRODUCTORY.

As commonly employed, the remedies known as anthelmintics are usually efficacious preparations. Their action is based on the premises that they are poisons which can be taken into the digestive tract of such animals as man, the horse, dog, or cat, in quantities not large enough to poison the host but sufficient to stupefy or kill verminous parasites with which they come in contact. The parasites are usually in the small intestine (intestinal helminthiasis) and occasionally in the stomach (gastric helminthiasis). In order to avoid dilution of the medicine, and also to give a more effective contact with the parasite, the patient is prepared in advance by fasting to empty the stomach and intestine. Finally a purgative is administered to carry out the dead or stupefied worms. All this is comparatively simple and in practice effective.

Though anthelmintics may be used very successfully in treatment for parasites in the stomach and small intestine of certain animals, they are, as a rule, less satisfactory when applied to ruminants. Medicines administered to ruminants must first pass the first, second, and third stomachs, some or all of which are usually well filled with food and difficult to empty in any reasonable period of fasting, before reaching the usual location of gastric parasites, the fourth stomach, through which in turn the medicines must pass before they reach the small intestine. In some cases, however, gastric and intestinal helminthiasis in ruminants may be treated successfully. Perroncito (1885)[1] and Stiles (1902), for example, have reported satisfactory results from the use of various remedies for stomach worms of sheep. Certain experiments have indicated that under the right conditions remedies may pass directly through the first stomach and thus arrive more or less promptly in the second and following stomachs and the intestine. Powers (1909), however, has questioned this, and considers medicinal treatment for stomach worms in ruminants unsatisfactory.

As to the treatment of parasites located in the large intestine, it has been found in actual practice, even in animals with simple stomachs and short alimentary tracts, such as the dog, that the results from the administration of remedies per orem are generally very unsatisfactory. Stiles and Pfender (1902), for instance, found that thymol, a classic remedy for hookworms, was without effect on whipworms of the cecum of the dog. On the other hand, Miller (1904) claims to have succeeded in removing whipworms from the dog by the use of oleoresin of male fern. Parasites located in the large intestine are, however, difficult to reach with ordinary anthelmintics administered by mouth.

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[1] References to literature will be found in bibliography at end of bulletin.

In view of the difficulty of reaching parasites located in the alimentary tract beyond the stomach or small intestine, or even in these organs in ruminants, by means of anthelmintics administered through the mouth, it would seem on first thought that treatment with such remedies for worms in the liver, pancreas, muscles, brain, blood, or in other locations outside the direct course of the digestive tract, would be certain to result unsuccessfully. Nevertheless several more or less commonly used anthelmintics have received favorable consideration in the treatment of verminous parasites located outside the lumen of the stomach and intestine, and the results of the tests made in some cases apparently afford a basis for a belief in their efficacy.

HISTORICAL REVIEW.

A consideration of the work done on this subject shows that writers, in general, have recognized two lines of work: First, the treatment of somatic and extraintestinal tæniasis where parasites are located in the brain, muscles, liver, or subcutaneous tissue; and second, the treatment of certain forms of distomatiasis, where the parasites are located in the liver or blood. Parasites in the liver are, of course, relatively nearer the usual site of operation of anthelmintics. To the first line of work we wish to add some notes on the treatment of tæniasis where the parasites are located in the liver and in the pancreatic and bile ducts. In this case the parasite, *Thysanosoma actinioides*, is also an intestinal parasite, and we use, therefore, the terms extraintestinal and intestinal thysanosomiasis to indicate the two forms of infestation with the adult worm.

Since writers along either of the two lines mentioned have usually confined their abstracts and criticism of related work to work along the one line, this review will summarize the two lines of work separately.

SOMATIC AND EXTRAINTESTINAL TÆNIASIS.

Zürn (1882a) states that after trying for 24 years to find some medication that would cure gid in sheep, he has concluded that successful treatment of the sort is impossible, and cautions against the administration of poisons, which, in his opinion, results in nothing but a waste of time and money. It is unfortunate that he did not give his experiments in detail, or at least name the remedies he tried; but from the fact that he speaks of them as poisons it seems reasonable to suppose that he tested the various common anthelmintics, all of which are poisons.

Curtice (1889a and 1890c) records tests of various remedies in intestinal and extraintestinal thysanosomiasis of sheep, and says:

> Various tæniafuges were tried with little success. The powdered preparations of pumpkin seed, pomegranate-root bark, koosoo, kamala, male fern, and worm seed proved of no avail. * * * The presence of tæniæ in the biliary ducts is another reason why tæniafuges can not be entirely successful in treatment of sheep with *T. fimbriata* [*Th. actinioides*]. Any medicine which would affect the tæniæ in these ducts would also affect the sheep seriously. It is doubtful whether they can be killed or driven from the ducts.

Feletti (1894c) administered ethereal extract of male fern in three cases of human cysticercosis, as follows:

> 1. Patient had had *Tænia solium*. Present symptoms: Convulsions, cephalalgia, vertigo, vomiting. Small subcutaneous nodules appeared and grew to the size of olives; one of these was excised and found to be *Cysticercus cellulosæ*. No cestode proglottids or eggs were found on fecal examination. Feletti administered 1 to 3 grams of extract of male fern per diem to the patient until he had given 18 grams. The patient could not stand more. The cysticerci diminished to the size of a wheat grain, but the cerebral trouble did not improve, and the man died a month later. No autopsy was permitted.
>
> 2. Patient had 34 subcutaneous nodules. One of these was excised and found to be *Cysticercus cellulosæ*. No cestode proglottids or eggs found on fecal examination. Feletti at first administered 1 to 1.5 grams of extract of male fern per diem, but this was not supported and the dose was accordingly cut down to 40 centigrams. The total amount administered was 26.5 grams. The nodules diminished until they could not be felt.
>
> 3. Patient had had a tapeworm three years before and had not recovered the head in several attempts at removal. Present symptoms: Convulsions, vertigo, and vomiting. For this he was treated with sodium and potassium bromid. Seven nodules developed. One of these was excised and found to be a cysticercus. Feletti administered 60 centigrams of extract of male fern per diem, and in a month the nodules had disappeared. The nervous condition was improved, but the trouble subsequently recurred and was treated with bromids with good results. Feletti thinks the recurrence was due to brain alterations, but considers that the cysticerci were dead.

According to Feletti, these cases demonstrate that extract of male fern kills subcutaneous and muscular cysticerci and that it probably acts upon cerebral cysticerci also. He advises a dose of 30 to 40 centigrams per diem for 30 or 40 days.

De Renzi (1908) renewed the interest in this line of work by his report of the administration of extract of male fern in four cases of human somatic tæniasis. We quote the following abstract of De Renzi's cases from Hall (1909):

> 1. The patient had occasion to eat badly cooked pork and uncooked sausage; had an infection with *Tænia solium* five years previous; had attacks of con-

vulsions and insensibility three years later, and on treatment with a vermifuge had passed a tapeworm with the head. Two months later the patient had stronger convulsions, dizziness, and shortness of breath on slight exertion. About this time growths appeared on the temples and the sternocleidomastoideus. Five months later the patient had three cramp-like attacks in one day, followed by great exhaustion. At this time the patient came to De Renzi, who found small swellings over the entire body and great nervous depression. On the history given here he diagnosed cysticercus of the brain and skin. After a year's ambulant treatment with male fern the nervous trouble had disappeared, so had the swellings, with the exception of one over the left temple, and this was removed by operation and showed the presence of a cysticercus. The eosinophilia present at the beginning of the treatment had disappeared.

2. The second patient, a woman, had an infection with *Tænia solium* three years before. For two years previous to treatment she had suffered from dizziness, headache, weak memory, polyuria, and weakness. A swelling over the manubrium sterni showed all the characteristics of a cysticercus. After a week's treatment the nervous symptoms had disappeared and the swelling was reduced to one-third its original volume. A microscopic examination of the swelling was made, but De Renzi states that in this examination nothing of special importance was noted.

3. In De Renzi's third case there was a history of increasing pain in the hypochondrium for 20 months, no fever or emaciation, increase in the area of liver dullness, eosinophilia present, urine normal. The case was diagnosed as hepatic echinococcosis, and all symptoms disappeared under treatment in 20 days. * * * Fecal examination did not show parasites or their eggs.

4. The fourth patient was a woman who had suffered for a year with a pain in the thorax and often coughed blood. In the absence of tubercular symptoms and because the patient coughed up membranes, "Häutchen," a diagnosis of lung echinococcosis was made by De Renzi and confirmed by two associates. In the brief period of six days she was cured by male fern.

Dianoux (1909) has recorded a case in which ocular and subcutaneous cysticercosis, possibly complicated by cerebral cysticercosis, was apparently cured by the administration of male fern.

Before coming under Dianoux's care, March 25, the patient had had several epileptiform attacks, and had nearly lost the sight of the left eye. Examination with the ophthalmoscope showed the presence of a cysticercus in the vitreous humor, and some weeks later a nodule, presumably a cysticercus, was found beneath the skin of the groin. After treatment with male fern and calomel the patient passed 4 or 5 meters of tapeworm (*Tænia solium*). May 2 the patient experienced an epileptiform convulsion. From May 3 to 20 the patient took 2 grams of extract of male fern per day; treatment was then suspended a few days. On May 24 a slight epileptiform attack occurred. Examination with the ophthalmoscope showed that the cysticercus had become shriveled and motionless. From May 25 to June 5, 2 grams of extract of male fern per day were administered. June 12 the cyst in the groin was discovered. June 16 an epileptiform attack occurred, lasting 15 minutes, and the following day there was another attack. Treatment was resumed. July 2 treatment was suspended; the cyst had disappeared from the groin; the general health of the patient was excellent. During 10 days in August the patient was given 1.5 grams of extract of male fern per day. November 15 the patient was discharged as cured. The cysticercus had entirely disappeared from the eye. The only evidence of its former presence was a cicatrice and vascular condition of the retina at the point where the parasite had been located. Altogether 102 grams of extract of male fern had been administered during a period of 71 days, and presumably as a result of this treatment a cysticercus of the eye, one under the skin of the groin, and probably others in the motor centers of the brain, had degenerated and become absorbed. Dianoux concludes that male fern destroys cysticerci because of some selective action against these parasites.

Railliet in his abstract of De Renzi's article (De Renzi, 1909) has noted that it would be interesting to test male fern on domestic animals suffering from parasitic diseases of the muscles and viscera, and mentions gid as one disease in which this treatment should be attempted. Such treatment was attempted and reported by Hall (1909). The treatment was tried on three sheep as follows:

1. Sheep showed characteristic symptoms of gid. Fifty grams of male fern powder administered on two consecutive days. The third day the attendant accidentally got the dose in the windpipe of the sheep, killing the animal. Post-mortem examination showed a large living cœnurus in the cerebrum.

2. Sheep showed pronounced symptoms of gid. Ethereal extract of male fern administered in 5 c. c. doses on 27 days between April 22 and May 30, a total of 135 c. c. Sheep found dead May 30, following a gradual increase in unfavorable symptoms from May 1. Post-mortem examination showed a large living cœnurus in the cerebrum.

3. Sheep showed characteristic symptoms of gid. Ethereal extract of male fern administered in 5 c. c. doses on consecutive days, with the exception of one day, until a total of 45 c. c. had been given. No improvement in condition. Treatment discontinued and sheep found dead four days later. Post-mortem examination of the brain showed a small live cœnurus.

Hall has given a critical review of De Renzi's cases, and concludes that they are open to suspicion of error as regards diagnosis and the connection between the disease, the treatment, and the cure.

Moussu (1910) has also reported some tests of ethereal extract of male fern administered for two months to two giddy sheep. There was a marked amelioration of symptoms, but at the autopsy, two months after the cessation of treatment, there was a cœnurus in the brain of each, very large in one case and the size of a hazelnut in the other, and neither of them degenerated. Moussu also tested the treatment on a pig affected with cysticercosis which had been developing for more than six months, the vesicles being readily visible under the tongue and the conjunctiva. The condition of the pig, instead of improving, became worse from day to day.

In view of the conflict between his results and those obtained by De Renzi and Dianoux, Moussu concludes that the influence of male fern only makes itself felt on young lesions and those in course of development, but that where the cysts are entirely developed the medicament remains entirely without effect.

The most recent published work upon this subject available to us is that of Dévé (1911). His test of the treatment was as follows:

Three rabbits were given a subcutaneous injection of brood capsules from a hydatid cyst. No. 1 was kept as a check. No. 2 was given each day for 52 days 4.5 c. c. of ethereal extract of male fern. The weight of the rabbit was 2.9 grams. No. 3, weighing the same, was given 9 c. c., or 6 c. c. per kilogram, or double the corresponding dose for man. The treatment was begun the same day as the injection. ' Five months later normal live echinococcus cysts were found in all three rabbits. From this Dévé concludes that in doses as large or twice as large as De Renzi used and extending over a much greater length of time the male fern was without effect on the hydatid cysts. The treatment showed itself incapable of affecting the delicate metamorphosis of the scolex, an initial phase in which it seems that the parasite would be especially vulnerable. Male fern is therefore provisionally deemed inefficacious in hydatid disease.

Dévé notes that his results in echinococcosis are in agreement with the negative results obtained by Hall in cysticercosis (Dévé's error; Hall's cases dealt with cœnurus, as noted above), by Moussu in cœnurosis, and finally with the very unsatisfactory results obtained by Railliet, Moussu, and Henry in distomatiasis.

A summary of the foregoing indicates that results following the administration of male fern were claimed as follows:

Successful in 6 cases of human cysticercosis (4 subcutaneous, 1 subcutaneous and cerebral, and 1 subcutaneous and ocular), and in 2 cases of human echinococcosis (1 hepatic and 1 pulmonary); a total of 8 cases of human somatic tæniasis.

Unsuccessful in 5 cases of ovine cerebral cœnurosis, 2 cases of leporine general echinococcosis, and 1 case of porcine muscular and ocular cysticercosis; a total of 8 cases of somatic tæniasis in lower animals.

A critical discussion of these cases will be given later. It is sufficient at this point to note that all tests on man were claimed to be successful and that all experiments on animals were failures. The cases of Zürn and Curtice are too indefinite to include in this summary.

DISTOMATIASIS.

Under this heading hepatic distomatiasis will be considered first and venal distomatiasis second.

Grassi and Calandruccio (1884 and 1885) record the first cases of which we are aware where extract of male fern was used in distomatiasis. The article published in 1884 is not available to us, but from the article of the following year it appears that they administered to sheep a single dose consisting of 5 grams of ethereal extract of male fern in 50 grams of ethereal tincture of male fern. They note that one might use injections of male fern, but that it would not always be necessary. The injection should consist of 1 gram of the ethereal extract mixed with 1 gram of the tincture and injected directly into the liver by means of a Pravaz syringe. A postscript, based on later work, adds that this injection should not be employed. They find that for 24 to 48 hours after the administration of the medicine the feces contained numerous flukes and nematodes. After three days the feces show no eggs, and on autopsy no flukes or strongyles are found. The number of tests and other details are not given.

They point out that this remedy should be tried in human distomatiasis, and that the injection method might be useful in echinococcus infections.

Perroncito (1886) has repeated the experiments of Grassi and Calandruccio and reports favorably on the use of male fern, noting, however, certain unfavorable results from its use. His experiments were as follows:

1. Sheep with symptoms of fluke disease. Fecal examination showed two to three eggs of *Strongylus*, probably *S. contortus*, and three to four fluke eggs per slide. Administered 10 grams of ethereal extract of male fern in 48 grams of ethereal tincture. The animal became tympanic, due to ethereal vapor developed in the stomach, and in a few minutes fell as if struck dead. After 40 minutes rose. At the end of 2 hours it had recovered from the symptoms of anesthesia and other phenomena of etherization. Some weeks later the feces showed one strongyle egg and one distome egg per slide.

2. Administered to sheep affected with liver fluke, 5 grams of ethereal extract of male fern in 50 grams of the tincture. Usual symptoms of flatulence and defecation. After 30 to 40 minutes sheep gradually returned to normal condition. Examination of the feces showed numerous distome and strongyle eggs. Two days later examination showed distome and hookworm eggs, but noticeably diminished in number. There had been 10 to 12 eggs per slide; there were now 4 to 5.

Two days later repeated the dose, substituting 6 grams of ethereal extract in place of 5 grams. The animal showed more severe symptoms than on the first occasion. There was considerable flatulence at the end of an hour.

Feces collected 40 hours after the second dose of male fern showed 2 to 3 distome eggs per slide. Animal seemed much improved. Seven days after the second dose the feces showed only one distome egg to three or four slides.

3. A sheep infested with a large number of liver flukes, about 800, was given a large dose of male fern and died in 10 or 12 hours. Autopsy showed that the flukes were apparently all dead.

This last case had been previously published by Perroncito (1885).

The next article dealing with experimental medication of hepatic distomatiasis which has come to our attention is that of Romagnoli (1903), who claims to have had good results in the treatment of distomatiasis in sheep from the daily administration of 1 grain of salol in a teaspoonful of water for 8 days. According to that author the salol kills the cercariæ which are still in the stomach and thus prevents further infestation, so that if the sheep are meanwhile given plenty of nourishment they rapidly recover their health and finally become completely cured. Romagnoli's treatment is of a different character from that reported by other writers in that it is supposed to act upon parasites during their invasion of the body and not upon those which have already become established in the host.

Floris (1907, 1908) has used carbon bisulphid, a remedy which Perroncito and Bosso (1894) and Wessel (1901) had reported as efficacious against *Gastrophilus* in the horse, and which Taar (1907) had found efficacious against *Gastrophilus* and *Ascaris* in the horse. Floris administered the carbon bisulphid in gelatin capsules in doses of 10 to 15 grams three or four times a week. The treatment was not attended by unpleasant effects and served to free the animals of flukes, the feces containing 5 to 10 flukes at a time. Floris notes that this is a very inexpensive remedy.

Alessandrini (1908) reports that he had administered extract of male fern to two sheep which were severely infested. The sheep were dead two days later. Autopsy showed the flukes in the intestine and liver to be dead and degenerated.

Pericaud (1908) has a rather glowing account of the virtues of a so-called " distomasine," said to consist of a glucosid and some plant essence. He gives no experimental tests, and the paper apparently adds nothing to our knowledge.

Borini (1911) states that in 1905, at the suggestion of Perroncito, ethereal extract of male fern was used to arrest a plague of bovine distomatiasis occurring on the estate of a rich proprietor in Calabria. Experiments have been made on laboratory animals from that year on, the treatment being especially tested on sheep. These experiments, according to Borini, confirm the therapeutic value of male fern against distomatiasis. In light infections cures were always obtained; in the worst cases of advanced cachexia the treatment failed. The use of thymol in connection with male fern is recommended.

Railliet, Moussu, and Henry (1911) have recently published a series of articles on the treatment of distomatiasis. In their first papers (1911a and 1911b) they note the desirability of some medication in view of the considerable losses suffered in France in 1910. They first experimented with medicines which may be eliminated by the liver, especially aloes, calomel, sodium salicylate, and "boldo." Most of the animals treated with these remedies improved, but there was no cure, no destruction of the parasites. Autopsy showed the flukes to be still alive after treatment extending over 15 days to three weeks. It seemed as though the treatment reduced the activity of the flukes without really having a specific effect on them.

In another series of experiments they used compounds of phosphorus, arsenic, and mercury, as phosphorated oil, arsenic, atoxyl, arseno-benzol, trypanblau, benzoate of mercury, and fluid extract of broom. None of them gave certain, positive results.

In a third paper (Railliet, Moussu, and Henry, 1911c) these authors report better success in their tests of a new series of substances, including particularly tartar emetic, urotropin, atoxyl, and ethereal extract of male fern.

The sheep used were for the most part heavily infested and had an intense cirrhosis and often a perforation of the capsule of Glisson, the flukes which caused the perforation escaping to the peritoneal cavity. Many had a mixed infection with *Fasciola hepatica* and *Dicrocœlium lanceatum.*

Tartar emetic and urotropin proved to be inefficacious. Atoxyl produced the evacuation of degenerated *F. hepatica* in one heifer.

The tests with ethereal extract of male fern were more satisfactory. An abstract is given of Alessandrini's (1908) experiments with male fern, noting this as the only work of the sort of which they were aware. Their own tests were made on five sheep, three others being kept as checks. The sheep were given 5 grams of ethereal extract in 25 c. c. of oil. Autopsy was made immediately after death. The experiments are as follows:

1. Sheep received one dose and died 12 hours later. Three hundred and ninety *F. hepatica* and numerous *D. lanceatum* in liver; all alive.
2. Sheep received two doses at 16-hour intervals and was killed in extremis 24 hours after the second dose. The biliary canals contained numerous live *D. lanceatum* and 55 *F. hepatica*, 4 of them being alive and the rest degenerated and of a yellowish-green color. The gall bladder contained 142 *F. hepatica*, all dead, though only 3 showed the same alteration as the preceding. The small intestine contained 16 degenerated specimens and the large intestine contained 10 dead but not degenerated specimens.
3. Sheep received three doses at 16 and 24 hour intervals. Killed 3 days after the last dose. Biliary canals contained several live *D. lanceatum*. There were 9 *F. hepatica*, all degenerated, in the gall bladder, but none in the biliary canals or in the intestine.
4. Sheep received four doses at 24, 24, and 48 hour intervals. Died 7 hours after the last dose. Biliary canals contained numerous live *D. lanceatum*. There were 5 degenerated *F. hepatica* in the gall bladder, none in the biliary canal, 1 degenerated specimen in the large intestine, and about 50 live specimens in the peritoneal cavity, associated with peritonitis.
5. Sheep received four doses at 48, 24, and 24 hour intervals. Killed 3 days after the last dose. Biliary canals contained several *D. lanceatum*, all living. There were no *F. hepatica* in the bile ducts, the gall bladder, or the intestine.

The three check sheep were killed at the end of the experiment and showed 178, 85, and 497 *F. hepatica*, respectively, and numerous *D. lanceatum*, all living.

The degeneration undergone by *F. hepatica* under the influence of male fern, and to a lesser extent of atoxyl, begins at the posterior extremity and progresses anteriorly, some individuals being green and flabby at the posterior end, while the cephalic end was still capable of movement.

They conclude that male fern is a satisfactory treatment for infection with *F. hepatica* if taken before there are irremediable lesions and at least four doses of 5 grams each administered. This will kill *F. hepatica* in the liver, but not in the peritoneal cavity. At the same time it is effective against gastrointestinal strongylosis. It has no effect on *D. lanceatum*.

In a later paper (Railliet, Moussu, and Henry, 1911d) these authors recapitulate the foregoing, noting the earlier work of Grassi and Calandruccio and of Perroncito. They add the following experiments:

> Four sheep were given 5 grams of ethereal extract of male fern in 25 c. c. of oil for four successive days, a fifth animal being kept as check. All the sheep showed fluke eggs in the feces. Four days after the last dose they were all killed. Autopsy showed the following:
>
> 1. Liver contained 1 *F. hepatica* (presumably alive), but marked lesions of cirrhosis indicated the recent disappearance of other flukes.
>
> 2. Liver contained 2 live *F. hepatica* in the terminal ducts and 3 dead and degenerated forms. Hepatic lesions moderated.
>
> 3. Liver, abnormal in appearance, contained 26 live *F. hepatica* and 1 dead one.
>
> 4. Liver contained 1 live *F. hepatica*.
>
> 5. Check animal. Liver strongly cirrhotic, contained 296 live *F. hepatica*.
>
> All animals contained a number of live *D. lanceatum*.

They conclude that male fern is effective, and, for sheep, suggest a dose of 1 gram of ethereal extract for every 5 kilos of live weight of animal; for cattle, about 30 grams for 350 to 400 kilos of live weight. They note that male fern is comparatively cheap and suggest that it be administered by means of a rubber tube.

The status of anthelmintics in bilharziasis is indicated in the following summary:

Stiles (1904) says: "Favorable results are claimed from repeated doses of male fern; some authors consider specific treatment futile."

Sandwith (1909) writes of bilharziasis:

> No method has as yet been discovered of killing the worms in the human body; the ordinary vermifuges are useless. * * * The liquid extract of male fern, in doses of 15 minims 3 times a day, is the only drug of known value, for, though it does not expel the parasites [How could it?], it seems to weaken their power of doing harm; it diminishes hematuria, allays vesical irritation, and reduces the number of eggs passed in the urine and feces.

Joannidès (1911) has tried salvarsan in bilharziasis in 8 cases, and reports that a single injection of 0.5 to 0.6 gram (?) of salvarsan in the case of adults and 0.25 gram (?) in the case of a 12-year-old child resulted in cessation or great diminution of hematuria, relief from vesical and urethral irritation, and a disappearance of the eggs from the urine. He concludes that salvarsan is destructive of *Schistosomum hæmatobium* and its eggs and thus brings about a cure of the disease.

Looss (1912) takes exception to the conclusions of Joannidès and states that bilharziasis is a disease characterized by lesions due to the passage through or retention in the tissues of the bladder, rectum, etc., of vast numbers of eggs, the parasite itself in the blood vessels having practically no direct pathological significance. By the time the patient goes to a physician for treatment for hematuria the worms producing the eggs which cause this are probably dead or near their end. Looss looks upon the cures reported by Joannidès as resulting from an artificial retention of the eggs in the tissues, causing thereby a suppression of the symptoms but not a cure of the disease. For the purpose of this article—a consideration of the question whether anthelmintics are effective against metazoan parasites located elsewhere than in the digestive tract—the question as to whether the killing of the fluke is desirable or not, or as to whether the bilharzia disease is, strictly speaking, one due to flukes or to fluke eggs, is not material. Looss does not attack Joannidès's conclusions that the embryos in the fluke eggs and possibly the adult flukes, also, are killed by salvarsan.

Conor (1911) has tried salvarsan in one case of bilharziasis and found it inefficacious. Eggs containing living miracidia were found in the patient's urine every day but one for a month after the treatment.

Fülleborn and Werner (1912) have also tried salvarsan in a case of bilharziasis, with the same negative result.

Day and Richards (1912) have criticized Joannidès's findings, and report three cases in which salvarsan was administered with no effect on the passage of living ova or, in two cases examined, on the eosinophilia.

A summary of the foregoing papers on the treatment of hepatic distomatiasis shows the following:

The administration of anthelmintics has been declared effective by Grassi and Calandruccio as a result of experiments (number not given) followed by fecal examination and post-mortem (male fern); by Perroncito after three experiment cases followed by fecal examination and post-mortem (male fern); by Floris after experiments (number not given) in which no autopsies or subsequent fecal examinations showing absence of eggs are noted (carbon bisulphid); by Alessandrini after two experiment cases followed by autopsy (male fern); by Borini after experiments (number not given) in which no autopsies or subsequent fecal examinations showing absence of eggs are noted (male fern and thymol); and by Railliet, Moussu, and Henry after nine experiment cases, four other animals being used as checks, followed by autopsy (male fern). This is a total of 14 detailed experiments and 2 other sets of tests with the number of animals not given. Romagnoli's treatment is omitted from consideration in this summary, as no claim has been made that it affects parasites already established in the host.

In the case of venal distomatiasis, male fern has been commended as being efficacious, with no data found by us on casual examination of the literature as to autopsy showing that the death of the fluke actually follows the administration of the male fern. Salvarsan has been commended on the basis of a cessation of symptoms following its administration in eight cases of bilharziasis, and opposed on the findings in five cases in which its administration was without effect. Looss questions the benefits of salvarsan as regards the organic lesions due to the parasite, while the other writers take exception to Joannidès's findings as not conforming to other known facts.

AUTHORS' EXPERIMENTS.

Being engaged in a study of tapeworm disease of sheep, due to *Thysanosoma actinioides*, the authors have taken advantage of opportunities to test carbon bisulphid and male fern as remedies for this disease. At the request of a sheep owner we also tested a certain proprietary remedy. This remedy was found on analysis by the Biochemic Division of the Bureau of Animal Industry to consist of 49 per cent ferrous sulphate, 13 per cent arsenious oxid, 8 per cent oxids of calcium, potassium, silicon, and magnesium, and 29 per cent organic matter, nature not determined but not containing santonin or any other vegetable alkaloid.

Tests of carbon bisulphid were made by the junior author at the ranch of Mr. Wells, near Resolis, Colo., in July, 1911. A Mexican herder at one camp was instructed to cut out six sheep, picking the poorest and weakest as being the most likely victims of thysanosomiasis. Events proved that some of the sheep selected were really too sick for the experiment.

The experiments were as follows:

1. Administered 6 grams of carbon bisulphid in capsule to a sheep. Sheep crushed one or two capsules and seemed greatly distressed thereby. Repeated dose after 30-hour interval. Sheep found dead the next day. Post-mortem showed appearances similar to those of hemorrhagic septicemia. A number of live bile-stained *Thysanosoma* found in the enlarged bile ducts and a number of others in the duodenum. One specimen of *Thysanosoma* was found with the head in the fourth stomach and the rest of the worm in the third stomach; this might have been due to post-mortem wandering or to a reverse peristalsis. Two specimens of *Cysticercus tenuicollis* were found adhering to the liver and one to the duodenum. The fluid content of the cysticerci was stained with blood. Death was perhaps hastened by the administration of the carbon bisulphid. Two doses of 6 grams each had not killed the tapeworms in this case.

2. Administered 6 grams of carbon bisulphid in capsule. Repeated dose after 30-hour interval. Sheep found dead the next day. Post-mortem showed appearances similar to those of hemorrhagic septicemia; death perhaps hastened by the administration of the carbon bisulphid. There were no tapeworms anywhere, and no lesions, such as thickened and enlarged bile and pancreatic ducts, to show that there had been any tapeworms.

3. Administered 6 grams of carbon bisulphid in capsule. Repeated dose after 30-hour interval. Sheep found dead the next day. Post-mortem showed

appearances similar to those of hemorrhagic septicemia. Death was perhaps hastened by the administration of carbon bisulphid. No *Thysanosoma* or lesions attributable to this worm were found.

4. Administered 6 grams of carbon bisulphid in capsule. Fifty hours later administered 4.5 grams of carbon bisulphid and repeated this dose 24 hours later. Killed the sheep 20 hours afterwards. No tapeworms were found on autopsy, but the gall ducts were thickened and enlarged, as was also the pancreatic duct, probably the result of former infestation with *Thysanosoma*. No worms had been found, however, in the feces of this or any of the other sheep.

5. Administered 6 grams of carbon bisulphid in capsule. Fifty hours later administered 3.5 grams of carbon bisulphid and repeated this dose 24 hours later. Killed the sheep 20 hours afterwards. No tapeworms were found on autopsy.

6. Administered 6 grams of carbon bisulphid in capsule. Forty-eight hours later sheep was down, with a respiration rate of 210. Sheep found dead 24 hours later. No evidences of the efficacy of the drug—that is, dead specimens of *Thysanosoma*—were found. Other notes regarding this autopsy lost.

A summary of the above experiments shows that sheep No. 1 had live tapeworms in the liver and intestines after receiving two doses of 6 grams each of carbon bisulphid on two successive days; that Nos. 2 and 3 after the same treatment had no tapeworms or lesions indicating their presence; and that Nos. 4, 5, and 6 showed no dead tapeworms on autopsy. As stated before, no tapeworms were found in the feces of any of these sheep. These experiments were inconclusive, but they point to the inefficacy of carbon bisulphid in that where tapeworms were found, as they were in one case, after 12 grams of carbon bisulphid had been administered, the tapeworms were alive.

It should be noted in this connection, as a matter of passing interest, that no stomach worms were found in these sheep on post-mortem.

The next set of experiments was made by both of us at Mr. Wells's ranch later in July. This time four sheep, selected as probably suffering from *Thysanosoma* infection, were used to test the ethereal extract of male fern, and two sheep in good condition were used to test the proprietary medicine previously referred to. The experiments were as follows:

Sheep Nos. 1 and 2 were given two tablets each of the proprietary medicine, according to the directions furnished with the medicine. No. 1 was killed 24 hours later. A number of *Thysanosoma* were found in the gall bladder and intestine, and *Hæmonchus contortus* and *Ostertagia bullosa* in the fourth stomach. All the worms were alive, although the advertisement of the remedy claimed that the dose given would kill any worm in the digestive tract. No. 2 was killed 48 hours after receiving the dose. Specimens of *Thysanosoma* were found in the gall ducts, two in the pancreatic duct, and a number in the intestine; *Hæmonchus* and *Ostertagia* in the stomach. All the worms were alive.

The analysis, already given, of this medicine, indicated that it is practically inert as a vermifuge and that any improvement following its use would be attributable to the tonics contained in it. The negative results with this medicine were precisely what might be expected. At a time when parasitologists in practical work are not aware of adequate remedies for all kinds of worms, and especially of any one remedy which is efficacious against all kinds of worms, it is unlikely that the manufacturers of proprietary medicines will have this information.

In the male-fern experiment, sheep Nos. 3, 4, 5, and 6 were given 9 c. c. of the ethereal extract thoroughly mixed with 25 c. c. of linseed oil—the dose recommended by Railliet, Moussu, and Henry—in the morning of four successive days. They were killed the afternoon of the fourth day. No. 3 had one dead and partly digested *Thysanosoma* in the gall bladder; No. 4 had one live *Thysanosoma* in the gall duct and one live one in the pancreatic duct; Nos. 5 and 6 had no tapeworms. No *Hæmonchus* was found in any. Live *Ostertagia* were found in Nos. 1, 2, and 3. All of the sheep had some signs of pneumonia, a marked retention of urine, with a slight cystitis, due apparently to the male fern. Considerable purging occurred during the last two days, which is attributable to the linseed oil. No tapeworms were found in the feces.

The finding of a dead *Thysanosoma* in the gall bladder of No. 1 is a fact pointing to a possible efficacy of the male fern; the presence of live *Thysanosoma* in No. 2 rather offsets this.

As the experiments were not conclusive, we repeated them later on the ranch of Mr. Kennedy, near Amo, Colo. Five sheep were selected, one of them being used as a check. Four sheep were each dosed with 6 c. c. of ethereal extract of male fern thoroughly mixed with 25 c. c. of linseed oil, on four successive days. The sheep were killed on the fifth day. Autopsy findings were as follows:

1. Twelve *Thysanosoma* in gall ducts and duodenum and 2 *Strongyloides papillosus* in intestine. No *Hæmonchus*.
2. Twelve *Thysanosoma* in duodenum, 1 in common bile duct, 4 in biliary ducts, 1 in gall bladder, and 1 in pancreatic duct, a total of 19; 4 *Hæmonchus* and 2 *Ostertagia* in fourth stomach.
3. Five *Thysanosoma* in duodenum, 1 in gall bladder, and 3 in bile ducts, a total of 9; 158 *Hæmonchus* in fourth stomach and 10 *Nematodirus filicollis* in intestine.
4. Seven *Thysanosoma* in duodenum and 5 in gall ducts, a total of 12; a few *Hæmonchus* and about 20 *Ostertagia* in fourth stomach.
5. Check animal. Two *Thysanosoma* in the gall ducts; a few *Hæmonchus* and *Ostertagia* in fourth stomach and 3 *Strongyloides* in intestine.

The *Thysanosoma* were all alive, as were the nematodes.

It appears from these experiments that male fern as administered is not efficacious against thysanosomiasis. While the negative findings of the former experience are inconclusive, the findings in this case are fairly conclusive. The failure of the medicine to exert any effect on four infected sheep indicates that male fern is not a remedy which could be recommended in thysanosomiasis.

GENERAL SUMMARY AND CRITICISM.

It appears from the foregoing that anthelmintics have been claimed to be efficacious in 8 cases of human somatic tæniasis (male fern); inefficacious in 8 cases of somatic tæniasis in the lower animals (male fern); inefficacious in at least 6 cases of intestinal and extraintestinal thysanosomiasis (carbon bisulphid and male fern); efficacious in over 14 cases of hepatic distomatiasis (carbon bisulphid and male fern); efficacious in 8 cases of venal distomatiasis (salvarsan); inefficacious in 5 cases of venal distomatiasis (salvarsan); and efficacious or inefficacious, according to various authors, in an indefinite number of cases of venal distomatiasis (male fern).

While the figures in the above paragraph are preponderantly in favor of the efficacy of anthelmintics against somatic helminthiasis, it should be borne in mind that there is much more likelihood of cases being published where the administration of a medicine is followed by apparent cure of disease than where it is followed by evident failure to cure. Further objections to the figures as they stand are based on a critical examination of the cases. This criticism may be summarized as follows:

Zürn's experiments are entirely indefinite and lacking in detailed statement. In Feletti's cases one patient died in spite of treatment and there was no autopsy, and in the other cases the possibility of spontaneous degeneration of the cysticerci, a not uncommon thing, is not excluded. De Renzi's cases, as we have already stated, have been criticized by Hall (1909) as open to suspicion of error as regards diagnosis and the connection between the disease, the treatment, and the cure. Dianoux's case is open to much the same criticism as those of De Renzi. Granting that the diagnosis was correct (as it apparently was in this case), the possibility of spontaneous degeneration of the parasites is not excluded, and it is not safe to conclude that their disappearance was due to the treatment. At least one of Hall's cases was not at all conclusive. None of the cases dealing with distomatiasis specifically eliminate the possibility of the natural death and spontaneous evacuation of the flukes, the usual ending of the yearly life cycle, although the use of check animals, where such checks were used, probably meets this objection. Perroncito's cases show that on the basis of fecal examination the flukes apparently were not killed in two cases out of three. Floris and

Borini cite no post-mortem findings or final negative fecal examinations in support of their statements. Among the cases reported by Railliet, Moussu, and Henry, autopsy showed that *Fasciola hepatica* in four cases and *Dicrocœlium lanceatum* in all cases had survived the full dose advocated by them. None of Joannidès's cases were followed by post-mortem examination; and, so far as case records are available, no cases of bilharziasis treated by male fern have been followed by post-mortem examination to ascertain whether the administration of the male fern had resulted in the death of the flukes.

In spite of these objections, the total evidence collected here indicates that further work along this line is necessary and desirable. It is possible that the common opinion that medicines administered per orem or subcutaneously can not be successfully used against metazoan parasites outside of the digestive tract, that the higher orders of parasites can not be killed by a selective action of drugs without injury to the host animal in whose tissues they are located, may be erroneous. Improved technic and better medicines have marked great advance in the treatment of protozoan and bacterial diseases. Similar improvements have led to greater success in the treatment of intestinal helminthiasis. May not careful experiment lead to the same results in the treatment of somatic and extra-intestinal helminthiasis? The subject is worth investigating. The location of metazoan parasites often makes surgical treatment impossible, dangerous, or unprofitable. Adequate methods of medicinal treatment would have great medical and economic value as well as scientific interest. The present state of our knowledge does not warrant any conclusion other than this, that a great amount of additional work is necessary and desirable.

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METHODS OF CLASSIFYING THE LACTIC-ACID BACTERIA.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Animal Industry,
Washington, D. C., March 22, 1912.

Sir: I have the honor to transmit for publication as a bulletin of this bureau the accompanying manuscript entitled "Methods of Classifying the Lactic-Acid Bacteria," by Messrs. Lore A. Rogers and Brooke J. Davis, of the Dairy Division of this bureau.

There has hitherto been felt a need by dairy bacteriologists and others of a classification of the lactic-acid bacteria into naturally related groups by means of characters that can be determined with reasonable accuracy and in a manner ordinarily available. This paper describes the study of about 150 cultures isolated from milk, butter, and cheese, derived from various parts of the country, with the object of laying the basis for a satisfactory classification.

Respectfully,

A. D. Melvin,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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METHODS OF CLASSIFYING THE LACTIC-ACID BACTERIA.

INTRODUCTION.

The grouping of bacteria according to their action on any one specific substance usually brings together bacteria related in that one characteristic only but entirely unrelated in other respects. It is, however, sometimes convenient from a technical standpoint to group bacteria in this way. The bacteria concerned in the souring of milk have been so grouped for so long that many people have come to consider them as a division by themselves and their relation to other bacteria has been little considered. The bacteria taking part in the souring of milk may be readily divided into four general groups.

Group I includes those bacteria which sour milk without peptonization or gas formation; they grow poorly on artificial media and fail to liquefy gelatin. Morphologically they show some variation, usually appearing as a coccus or very short bacillus in pairs or in chains of varying lengths. The bacteria of this group are the ones ordinarily designated as the lactic-acid bacteria and have been described under various names. They have a very general distribution and their presence in milk is so constant that they may be considered as normal inhabitants of this medium.

Group II includes the bacteria forming an acid curd with evolution of gas. This embraces varieties of *Bacillus coli* and *Bacterium aerogenes* or the *Bacillus acidi lactici* of Heuppe. The members of this group are readily distinguished from those of Group I by their abundant growth on artificial media, the vigorous evolution of gas, and the marked difference in their morphology. An examination of milk usually reveals their presence in small numbers, but their number is increased by the influence of high temperatures or insanitary conditions under which the milk has been collected or held.

Group III includes those bacteria forming an acid curd which is subsequently partially peptonized. The bacteria of this group have been little studied in their relation to milk. It will be shown that this description applies to varieties only distantly related to our Group I as well as to some closely connected with this type.

Group IV includes the high-acid-forming bacteria of which the *Bacillus bulgaricus* is the type. This organism is distinguishable from those of the preceding groups by its slender rodlike form, its characteristic colonies on agar, its inability to grow in ordinary artificial media, and its growth in the presence of free acid. *Bacillus bulgaricus* has been studied in its relation to the fermented milks extensively used in Turkey and the neighboring countries. It has recently been shown[a] [1], [2], [3], that it is very widely distributed and may be isolated from almost any sample of mixed milk. Its growth at normal temperatures is so slow that it is improbable that it is a factor in the ordinary souring of milk.

It is obvious that these groups are connected only by their ability to ferment lactose to acid and the consequent precipitation of the casein. Groups I, II, and IV are evidently related to each other in no other way. The identity of the bacteria of Group III in so far as they occur as milk bacteria has not been established. The need of work on methods of classification rather than on descriptions of new varieties or rearrangement of old names and descriptions is exemplified by the confused nomenclature of the bacteria included under Group I. We find in the literature such names as *Bacterium lactis acidi*, *Bacillus lactis acidi*, *B. acidi lactici*, *B. guntheri*, and *Streptococcus lacticus*, all of which, so far as can be determined by published descriptions, may be included in Group I. These names are based on variations in morphology, differences in growth on artificial media, on the rate of acid formation in milk, and various other characteristics of doubtful significance and uncertain stability. In the light of recent investigations these names and their accompanying descriptions have little more than a historic interest. They represent the attempt to establish types by the study of an isolated individual organism with little regard to its relation to other similar individual organisms.

Approached from the standpoint of the dairy bacteriologists, the lactic-acid bacteria have been considered as a sharply defined group peculiar to milk. The students of pathogenic bacteria have been inclined to look on them as a variety of some of the pus-forming streptococci.

The opinion that the term lactic-acid bacteria covers a group of species or varieties and that the names and descriptions already published do not represent the true grouping is reflected in the frequent attempts to establish means of separating the group into stable species or varieties. McDonnell[4] attempted to do this, basing his descriptions largely on the effect on milk. A somewhat similar course was followed by Weigmann.[5] Müller[6] found a correlation in the solution of red blood corpuscles and the agglutination of immune sera by the streptococci of sour milk and certain pathogenic streptococci, and considered that this indicated a relationship. Lohnis[7] has made a classification of the lactic-acid bacteria based largely on gas formation, coagulation of milk, formation of slime, and liquefaction of gelatin. Conn, Esten, and Stocking[8] have used in their descriptions the action on milk and the usual culture characteristics. Heinemann[9] as a result of his studies on the bacteria of sour milk, excludes the name of *Bacillus acidi lactici*, and concludes that aside from the part taken by *B. aerogenes* and possibly by *B. coli* the spontaneous souring of milk is brought about by the *Streptococcus lacticus* of Kruse, an organism identical with the common streptococci of sewage and pathological conditions. He bases this conclusion on the similarity in morphological, cultural, and pathogenic properties.

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[a] The reference figures relate to the list of references to literature at the end of this bulletin.

All of this work and much more of a similar nature adds little to the systematic arrangement of the lactic-acid bacteria. It is generally admitted that it is difficult to identify cultures of any but the best known and most carefully studied bacteria by the published descriptions. Cultures which seem identical when written descriptions are compared are found to be distinct when they are grown side by side under uniform conditions. This error in identification is due partly to the difficulty of conveying the appearance of an object by words, but in a larger degree to the instability and unessential nature of some of the characters employed in separating one bacterial species or variety from another. The inadequacy of the ordinary methods is particularly felt when one attempts a description of the lactic-acid bacteria. The cells are small and the morphological differences are uncertain and inconstant. The growth on solid media is scanty and devoid of distinguishing characteristics. While many of the physiological tests which are found of great value in some groups fail when applied to the lactic-acid bacteria, others, notably the acid fermentations of sugars, offer a possible means of differentiation for members of this group.

Variations in the ability to ferment sugars have been observed, but the use of these variations in classifying or identifying cultures has been limited for two reasons. There has been a belief that the fermentative power was not constant; that this property could be lost or acquired so readily that it could not be used to differentiate one culture from another with any certainty. The more common objection, however, is that the separation on the basis of sugar fermentation divides the lactic-acid bacteria and others possessing the same general characteristics, not into natural groups, but into innumerable varieties.

The use of tests of this kind in the usual way by which the fermentation of, or failure to ferment, a certain substance sets the culture so reacting apart from all other cultures gives an endless dichotomy limited only by the number of test substances. Consequently, the ordinary use of sugars has increased rather than diminished the confusion now existing in the classification of the zymogenic bacteria. It is obvious that what is required in systematic bacteriology is not descriptions of new species or a rearrangement of names, but the establishment of means of classification applicable technically and correct biologically. No one basis of classification can be used for all groups of bacteria, but certain fundamental principles should govern any method of arrangement. Two of the most obvious principles on which the selection of characters for classification should be based may be stated as follows: The characters should be constant; they should be so selected that they show real biological relationships. In other words, bacteria should be arranged by means of characters that can be determined with reasonable accuracy and by means ordinarily available into groups whose members are related naturally rather than by artificial bonds, and these characters should be so constant and so distinctive that identical organisms can always be placed in the same group.

This paper records an attempt to determine which of the characters exhibited by the lactic-acid bacteria fulfill these conditions. No attempt has been made to classify or name any members of this group or to fix its place in the general bacteriological system.

THE SIGNIFICANT CHARACTERS OF THE LACTIC-ACID BACTERIA.

The morphology, staining reactions, cell grouping, cultural characters, and growth in milk were considered, but more attention was given to the fermentation tests. We studied about 150 cultures isolated from milk, butter, and cheese obtained from various parts of the country. This collection included, in addition to the typical milk-curdling, nonliquefying, lactic-acid bacteria, a number of cultures curdling milk with subsequent digestion and which formed on gelatin plates small saucer-shaped liquefactions surrounding a solid colony.

We have determined on these cultures the morphology, Gram's stain, cell grouping, in many cases formation of capsule, the nature and amount of growth on lactose-agar slopes and in gelatin stabs, the rate of liquefaction of gelatin, the nature of growth in broth, growth in milk, the reduction of nitrates and of neutral red, and the formation of acid in broth containing various test substances. In these fermentation tests we have used the sugars lactose, dextrose, galactose, saccharose, and raffinose, the alcohols mannite and glycerin, and the polysaccharid inulin. The results of these determinations are given in Table 1.

Table 1.—*Significant characteristics of acid-forming bacteria derived from milk, butter, and cheese.*

Culture.	Agar.		Capsule.	Gram stain.	Cloudiness in broth.	Reduction of neutral red.	Curdling of milk.	Reduction of nitrates.	Mm. gelatin liquefaction 30 days at 20°.	Per cent lactic acid in broth after 7 days at 30° C.							
	Good.	Scanty.								Dextrose.	Lactose.	Saccharose.	Glycerin.	Mannite.	Galactose.	Raffinose.	Inulin.
6es	....	+	+	+	+	....	+	−	0	0.360	0.319	0.000	0.000	0.000	0.198	0.000	0.000
6ex	....	+	+	+	+	....	+	−		.612	.360	.540	.000	.000	.234	.009	.009
6ez	....	+	....	+	+	....	+	−	0	.351	.450	.522	.000	.009	.216	.000	.018
6fa	....	+	....	+	+	....	+	−	0	.382	.423	.000	.000	.000	.324	.000	.009
6fb	....	+	+	+	+	....	+	−	0	.405	.378	.477	.000	.000	.378	.000	.000
6fl	....	+	....	....	+	....	....	+	0	.288	.315	.405	.200	.279	.081	.171	.000
6fn	....	+	+	+	+	....	+	−	0	.364	.316	.000	.000	.000	.288	.000	.009
6fr	....	+	....	+	+	....	+	−	0	.668	.315	.000	.000	.000	.270	.000	.009
7b	....	+	....	+	+	−	−	−	0	.558	.378	.531	.000	.000	.297	.000	.009
7c	....	+	+	....	+	−	+	−	0	.400	.432	.000	.000	.000	.342	.000	.000
7d	....	+	....	....	+	−	+	−	0	.378	.414	.450	.027	.000	.283	.000	.009
7f	....	+	....	+	−	....	+	−	0	.693	.378	.405	.000	.000	.306	.000	.009
7g	....	+	....	+	+	....	+	−	0	.365	.414	.000	.000	.000	.315	.000	.000
7i	....	+	....	+	−	....	+	−	0	.324	.414	.000	.018	.000	.342	.000	.009
7j	....	+	....	+	−	....	+	−	0	.274	.387	.405	.000	.000	.054	.000	.009
7k	....	+	....	+	+	−	+	−	0	.369	.396	.000	.000	.000	.342	.000	.009
7n	....	+	....	+	+	....	+	−	0	.493	.333	.000	.000	.000	.405	.000	.018
7o	....	+	....	+	+	....	+	−	0	.423	.387	.000	.000	.000	.423	.009	.000
7p	....	+	....	+	+	....	+	−	0	.378	.378	.000	.000	.018	.397	.000	.009
7q	....	+	....	+	+	....	+	−	0	.360	.360	.000	.000	.252	.351	.000	.009
7s	....	+	....	+	+	....	+	−	0	.360	.369	.531	.000	.000	.189	.000	.000
7t	....	+	....	+	+	....	+	−	0	.585	.405	.526	.000	.252	.396	.009	.018
7u	....	+	....	+	+	....	+	−	0	.383	.324	.594	.000	.225	.242	.000	.018
7w	....	+	....	+	+	−	+	−	0	.306	.324	.009	.000	.000	.324	.000	.000
7x	....	+	....	+	+	....	+	−	0	.594	.378	.000	.000	.324	.369	.000	.009
7y	....	+	....	+	+	....	+	−	0	.504	.369	.000	.000	.000	.315	.000	.000
7z	....	+	....	....	−	−	+	−	0	.288	.171	.000	.000	.360	.108	.000	.009
7aa	....	....	....	+	+	....	−	+	0	.540	.306	.000	.283	.283	.225	.000	.000
7ab	+	....	....	....	−	−	+	−	0	.000	.162	.009	.018	.000	.378	.009	.000
7ad	....	+	....	+	+	−	+	−	0	.522	.351	.000	.000	.000	.216	.000	.009
7ae	....	+	....	+	+	....	+	−	0	.396	.360	.000	.000	.000	.306	.000	.009
7af	....	+	....	+	−	....	+	−	0	.351	.369	.000	.000	.000	.099	......	.000
7ag	....	+	+	+	+	....	+	−	0	.567	.351	.000	.000	.000	.252	.000	.009
7ah	....	+	....	+	+	....	−	−	0	.432	.378	.252	.000	.207	.000	.009	.009
7ai	....	+	....	+	....	....	+	−	0	.603	.360	.000	.009	.000	.414	.000	.009
7aj	....	+	....	....	....	....	−	−	0	.594	.270	.000	.027	.324	.153	.000	.009
7ak	+	....	....	+	+	....	+	+	0	.468	.306	.000	.234	.315	.297	.000	.009
7ao	+	....	....	−	....	....	+	−	....	.585	.495	.423	.072	.018	.234	.000	.000
7ap	....	+	....	+	....	....	+	−	....	.630	.369	.027	.000	.081	.234	.000	.009
7aq	....	....	....	....	....	....	....	....	....	.360	.261	......	.000	......	......	.027	.009
7ar	....	+	....	+	....	....	+	−	....	......	.279	.378	.000	.342	.216	.009	.009
7as	....	+	....	+	+	....	+	−	....	.702	.360	.000	.072	.009	.234	.000	.036
7ay	....	+	+	+	+	....	+	−	....	.513	.423	.000	.009	.009	.189	.000	.000
7ba	....	+	....	+	+	....	+	−	....	.702	.369	.054	.000	.018	.243	.000	.000
7be	....	+	....	....	−	−	+	−	0	.288	.171	.009	.342	.000	.171	.000	.018
7bg	....	+	....	....	−	−	+	−	0	.180	.279	.387	.036	.045	.252	.009	.009
7bi	....	....	....	....	+	−	+	−	0	.396	.342	.000	.009	.000	.360	.000	.000
7bj	....	....	....	....	+	−	+	−	0	.396	.324	.000	.009	.063	.396	.018	.000
7bn	....	....	....	....	+	−	+	−	0	.306	.189	.000	.009	.000	.288	.018	.000
7bp	....	....	....	....	−	−	+	−	0	.294	.207	.000	.009	.063	.306	.000	.000
7bq	....	....	....	....	....	−	+	−	....	.306	.036	.000	.000	......	.234	.018	.000
7br	....	....	....	....	−	−	+	−	0	.270	.342	.000	.009	.000	.378	.018	.000
7bs	....	....	....	....	+	−	+	−	0	.332	.396	.000	.000	.315	.396	.018	.009
7bt	....	....	....	....	−	−	+	−	0	.306	.297	.000	.000	.000	.360	.000	.018
7bv	....	....	....	....	....	−	+	−	0	.423	.360	.000	.027	.018	.333	.000	.216
7bx	....	....	....	....	....	−	+	−	0	.360	.216	.018	.054	.009	.288	.000	.009
7by	....	....	....	....	+	−	....	−	0	.549	.193	.009	.000	.018	.441	.009	.000
7bz	....	....	....	....	....	−	+	−	0	.297	.387	.693	.036	.000	.000	.000	.000
7ca	....	....	....	....	+	−	+	−	0	.441	.256	.000	.000	.036	.306	.000	.000
7cb	....	....	....	....	+	−	+	−	0	.378	.144	.027	.000	.018	.324	.000	.027
7cc	....	....	....	....	+	+	+	+	11	.360	.221	.288	.009	.397	.351	.009	.387
7cd	....	....	....	....	−	−	+	−	0	.558	.297	.009	.000	.018	.414	.000	.000
7ce	....	....	....	....	−	−	+	−	....	.351	.144	.225	.018	.009	.261	.000	.000
7cf	....	....	....	....	+	−	+	....	....	.225	.103	.009	.009	.018	.324	.000	......
7cg	....	....	....	....	−	+	+	−	0	.495	.297	.288	.153	.486	.333	.000	.000
7ch	....	....	....	....	+	−	+	−	0	.603	.248	.000	.000	.018	.414	.045	.009
7ci	....	....	....	....	−	+	+	−	0	.432	.260	.324	.036	.378	.423	.000	.000
7cj	....	....	....	....	−	−	+	−	0	.621	.270	.018	.018	.000	.243	.009	.000
7ck	....	....	....	....	....	−	+	−	0	.261	.297	.099	.036	.009	.302	.000	.018
7cl	....	....	....	....	....	+	+	−	0	.540	.648	.036	.045	.018	.315	.000	.000
7cm	....	....	....	....	+	−	+	−	0	.513	.261	.063	.000	.009	.306	.000	.018

TABLE 1.—*Significant characteristics of acid-forming bacteria derived from milk, butter, and cheese*—Continued.

Culture.	Agar.		Capsule.	Gram stain.	Cloudiness in broth.	Reduction of neutral red.	Curdling of milk.	Reduction of nitrates.	Mm. gelatin liquefaction 30 days at 20°.	Per cent lactic acid in broth after 7 days at 30° C.							
	Good.	Scanty.								Dextrose.	Lactose.	Saccharose.	Glycerin.	Mannite.	Galactose.	Raffinose.	Inulin.
7cn	....	....	....	....	+	−	+	−	0	0.378	0.234	0.000	0.000	0.018	0.477	0.000	0.000
7co	....	....	....	....	+	−	+	−	0	.351	.206	.099	.000	.027	.342	.009	.018
7cp	....	....	....	....	+	−	+	−	0	.576	.274	.027	.000	.000	.441	.225	.000
7cq	....	....	....	....	+	−	+	−	0	.576	.225	.009	.000	.009	.450	.000	.000
7cr	....	....	....	....	+	+	+	−	0	.459	.265	.009	.009	.243	.522	.000	.009
7cs	....	....	....	....	+	−	+	−	0	.522	.243	.000	.009	.117	.405	.027	.036
7ct	....	....	....	....	+	−	+	−	0	.684	.297	.000	.009	.036	.405	.000	.009
7cu	....	....	....	....	....	+	+	−	0	.261	.108	.009	.009	.009	.108	.000	.018
7cv	....	....	....	....	....	+	+	−	0	.351	.414	.531	.162	.531	.279	.630	.270
7cx	....	....	....	....	....	+	+	−	0	.316	.441	.459	.198	.549	.216	.630	.000
7cy	....	....	....	....	....	+	+	−	0	.423	.018	.029	.225	.504	.081	.648	.000
7cz	....	....	....	....	....	....	+	−	0	.495	.372	.009	.045	.045	.279	.018	.019
7da	....	....	....	....	....	+	+	−	0	.387	.423	.549	.117	.531	.234	.603	.306
7dc	....	....	....	....	....	−	+	−	0	.405	.432	.018	.099	.018	.036	.054	.000
7dd	....	....	....	....	....	+	+	−	0	.316	.396	.459	.045	.009	.378	.000	.000
7de	....	....	....	....	....	+	+	−	0	.279	......	.450	.198	.567	.252	.630	.252
7df	....	....	....	....	....	+	+	....	0	.369	.423	.477	.252	.558	.279	.648	.216
7dg	....	....	....	....	....	+	+	−	0	.333	.414	.522	.234	.558	.324	.630	.288
7dh	....	....	....	....	....	+	+	−	0	.369	.441	.531	.261	.558	.252	.603	.279
7di	....	....	....	....	....	+	+	−	0	.423	.414	.549	.162	.549	.279	.567	.288
7dj	....	....	....	....	....	+	+	−	0	.225	.405	.468	.234	.558	.243	.487	.261
7dk	....	....	....	....	....	+	+	−	0	.171	.405	.504	.198	.549	.261	.639	.000
7dl	....	....	....	....	....	+	+	−	0	.396	.450	.540	.234	.595	.279	.648	.306
7dm	....	....	....	....	....	+	+	−	0	.405	.009	.018	.000	.054	.153	.703	.000
7dn	....	....	....	....	....	+	+	−	0	.396	.432	.558	.027	.531	.288	.414	.297
7do	....	....	....	....	....	+	+	−	0	.288	.414	.522	.315	.549	.198	.676	.342
7dp	....	....	....	....	....	+	+	−	0	.216	.414	.540	.225	.567	.288	.639	.108
7ds	....	....	....	....	....	+	+	−	....	.432	.423	.549	.198	.558	.558	.261	.630
7du	....	....	....	....	....	+	+	−	0	.351	.441	.468	.180	.540	.234	.676	.306
7dv	....	....	....	....	....	+	+	−	0	.288	.441	.369	.216	.549	.270	.756	.270
7dw	....	....	....	....	....	+	+	+	0	.414	.414	.612	.252	.594	.288	.657	.306
7dx	....	....	....	....	....	+	+	−	0	.334	.423	.423	.180	.540	.198	.630	.000
7dy	....	....	....	....	....	+	+	−	0	.378	.441	.414	.189	.558	.270	.648	.000
7dz	....	....	....	....	....	−	+	−	0	.594	.432	.000	.000	.000	.288	.000	.000
10av	....	+	....	+	+	....	+	−	0	.531	.369	.000	.000	.000	.351	.000	.027
10aw	....	+	+	+	−	....	+	−	0	.378	.351	.000	.000	.054	.216	.000	.000
10ax	....	+	....	+	−	....	+	−	0	.522	.405	.000	.000	.018	.351	.000	.000
10bb	....	+	+	+	+	....	+	−	0	.477	.351	.540	.000	.000	.270	.000	.000
10bd	....	+	+	+	+	....	+	−	0	.486	.369	.000	.000	.009	.171	.000	.009
10be	....	+	+	+	+	....	+	−	0	......	.387	.000	.018	.000	.315	.000	.009
10bg	....	+	+	+	+	....	+	−	0	.495	.405	.000	.018	.000	.342	.000	.000
10bh	....	+	+	+	+	....	+	−	0	.468	.387	.000	.000	.000	.360	.009	.000
10bi	....	+	+	+	+	....	+	−	0	.432	.333	.000	.000	.000	.143	.000	.000
10bo	....	+	+	+	+	....	+	−	0	.603	.343	.000	.018	.000	.369	.000	.000
10br	....	+	+	+	+	....	....	−	0	.495	.369	.072	.009	.000	.225	.009	.009
10bt	....	+	....	+	−	−	+	−	0	.720	.045	.000	.000	.000	.036	.000	.009
10bl	....	+	+	+	−	−	....	−	0	.324	.108	.585	.000	.369	.063	.000	.009
13c	+	....	+	+	+	+	+	−	9	.234	.171	.027	.048	.072	.099	.000	.009
13f	....	+	+	+	+	+	+	−	14	.369	.216	.274	.207	.191	.239	.009	.018
13h	....	+	+	+	+	+	+	−	26	.324	.194	.009	.216	.406	.234	.000	.018
13i	+	....	+	+	+	−	+	−	5	.220	.144	.014	.027	.004	.099	.000	.009
13m	....	+	+	+	+	....	+	−	24	.360	.270	.000	.162	.243	.175	.000	.000
13o	+	....	+	+	+	−	+	−	21	.230	.144	.252	.072	.004	.036	.000	.018
13r	+	....	+	+	+	−	+	+	6	.211	.126	.153	.054	.009	.072	.009	.018
13t	....	+	....	+	+	−	+	−	10	.165	.144	.285	.081	.297	.144	.000	.036
13u	+	....	+	+	....	+	+	+	18	.270	.077	.351	.180	.135	.146	.027	.036
13w	....	+	....	+	....	+	+	−	13	.208	.275	.351	.086	.162	.198	.018	.018
13x	....	+	....	+	....	....	+	−	15	.149	.176	.198	.207	.230	.203	.018	.009
13y	+	....	+	....	+	−	+	+	25	.432	.316	.369	.315	.216	.135	.000	.009
13z	+	....	+	+	+	−	−	+	15	.099	.234	.297	.234	.297	.144	.000	.009
13aa	+	....	....	+	+	+	+	−	8	.207	.171	.036	.054	.018	.058	.009	.009
13ab	+	....	+	+	+	−	+	−	7	.243	.175	.192	.027	.045	.063	.045	.018
13ac	+	....	....	+	+	−	....	+	9	.250	.153	.045	.045	.036	.081	.000	.000
13ad	....	+	....	+	+	−	+	−	0	.495	.324	.018	.036	.018	.256	.027	.000
13ag	....	+	....	+	+	−	+	−	6	.652	.355	.018	.045	.009	.261	.000	.000
13ah	+	....	....	+	+	−	+	−	5	.216	.153	.036	.009	.009	.075	.018	.000
13ai	....	+	....	+	+	−	+	−	0	.633	.324	.018	.045	.018	.279	.000	.018
13aj	+	....	....	....	+	+	+	+	6	.171	.171	.045	.000	.000	.054	.000	.000
13ak	+	....	....	....	....	−	+	+	13	.180	.117	.045	.121	.027	.090	.036	......
13am	+	....	....	....	....	−	+	−	14	.198	.121	.054	.072	.018	.081	.054	......
13ap	+	....	....	+	....	....	....	+	5	.198	.144	.090	.036	.027	.287	.018	......

TABLE 1.—*Significant characteristics of acid-forming bacteria derived from milk, butter, and cheese*—Continued.

Culture.	Agar.		Capsule.	Gram stain.	Cloudiness in broth.	Reduction of neutral red.	Curdling of milk.	Reduction of nitrates.	Mm. gelatin liquefaction 30 days at 20°.	Per cent lactic acid in broth after 7 days at 30° C.							
	Good.	Scanty.								Dextrose.	Lactose.	Saccharose.	Glycerin.	Mannite.	Galactose.	Raffinose.	Inulin.
13ar	....	....	....	....	....	−	+	−	....	......	0.198	0.027	0.027	0.009	0.153	0.036	......
13at	+	....	....	....	....	−	+	−	18	0.162	.171	.054	.054	.027	.117	.063	......
13av	+	....	....	....	....	−	+	−	11	.171	.145	.045	.045	.000	.063	.036	......
13aw	+	....	....	+	....	−	+	−	7	.117	.135	.090	.036	.009	.090	.036	......
13ax	+	....	....	....	....	−	+	+	6	.126	.181	.000	.027	.000	.090	.009	......
13be	+	....	....	+	....	−	−	+	12	.216	.135	.054	.090	.000	.099	.027	......
13bg	+	....	....	....	....	−	+	+	13	.189	.136	.036	.072	.009	.054	.072	......
13bk	....	....	....	....	....	+	+	+	....	.297	.207	.126	.009	.009	.189	.018	......
13bl	....	....	....	....	....	−	+	+	....	.234	.117	.054	.036	.027	.108	.081	......

MORPHOLOGY.

The cultures examined showed four more or less distinct types. The liquefying group included a number of cultures of micrococci, with frequent grouping in tetrads. This was associated with good growth on agar and certain fermentative reactions which made them easily distinguishable from the liquefying cultures with the morphology of the typical lactic bacteria. The nonliquefiers, excepting a few cultures of micrococci, showed three variations. Cells may be nearly or quite round. When in this condition they are usually found in chains of four or more cells. Single cells or pairs of cells are almost always oval and sometimes are distinctly of the bacillus type. A slight variation is sometimes found in that the cells are somewhat pointed at one end. All of these types can usually be found in the same culture and not infrequently in the same microscopic field.

The question of the classification of the lactic-acid bacteria as cocci or as bacilli has been much debated and is yet in an unsettled condition. The formation of chains, on which much emphasis is placed by some writers, is not pertinent, as the tendency to form chains is as common among the bacilli as among the streptococci. In our present state of knowledge the proper placing of these bacteria is largely a question of opinion or of definition. No satisfactory settlement can be reached until we have sufficient knowledge to establish the natural relations of the lactic-acid bacteria with other groups. Even in this case it is probable that close relationship will be traced on the one hand with groups that are distinct cocci and on the other with groups that are unquestionably bacilli.

It may be stated in this connection that one of our cultures (7dv), not differing morphologically from other cultures of the typical lactic type, was actively motile. This culture was pronounced by Dr. Heinemann to be a typical *Streptococcus lacticus,* except that it did not curdle milk promptly.

All of these cultures stain readily and are Gram positive. A capsule could usually be demonstrated if the test was repeated under varying conditions, indicating that it is formed only under certain circumstances. The circumstances under which a capsule was found indicated that it was in some way connected with the acidity of the culture.

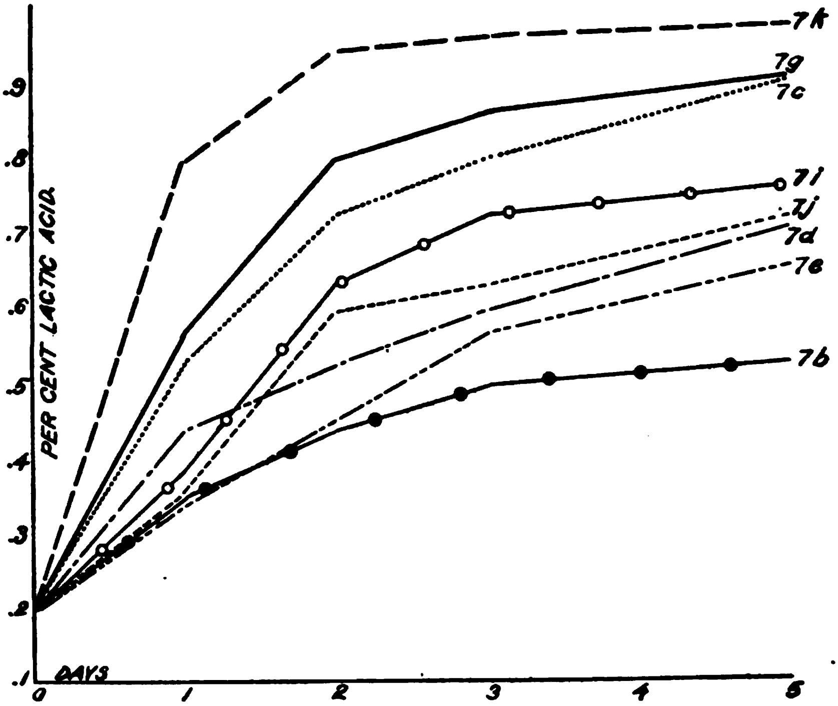

FIG. 1.—Rate of acid formation in milk at 30° C. by cultures freshly isolated from milk.

GROWTH ON SOLID MEDIA.

Little need be said under this head, although the growth of the lactic-acid bacteria on agar and gelatin has been described in great detail. The growth is always scanty, and the variations, which are very slight, are due more to differences in the chemical and physical condition of the medium than to varietal distinction.

Some real variation may be observed in the size of mature gelatin colonies, but this is so influenced by the medium and the number of colonies on the plate that it is of little value. Variations of this kind are probably merely expressions of a tolerance or intolerance to certain conditions which could be determined with much greater accuracy by other methods. The reaction of a particular lot of gelatin may produce large colonies of one culture while it limits the growth of another culture to colonies of almost microscopic size.

GROWTH IN MILK.

The time required to curdle milk under definite conditions has been employed almost universally in describing lactic-acid bacteria, although it is generally admitted that this property is variable, especially after the culture has been grown under artificial conditions. This variation is illustrated by figures 1 and 2.

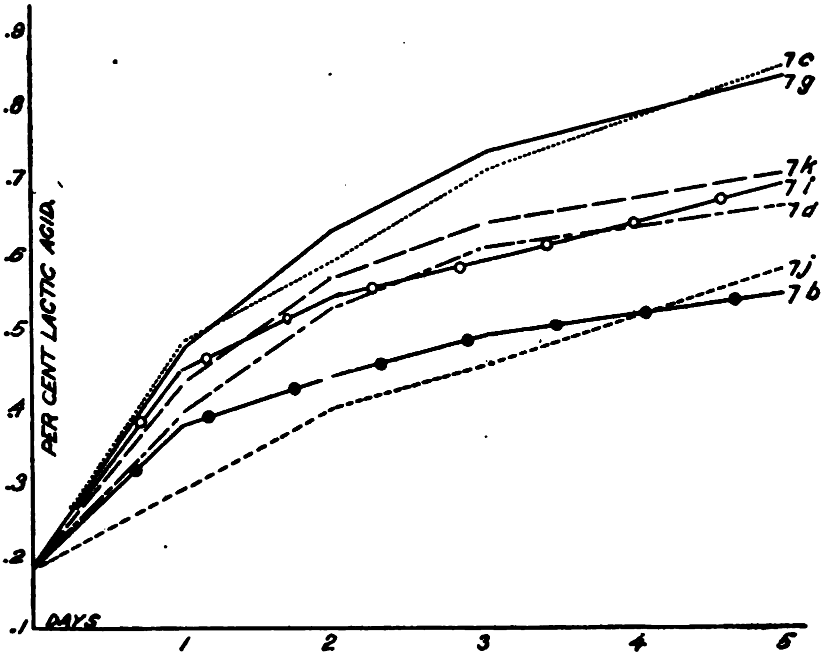

FIG. 2.—Rate of acid formation in milk at 30° C. after 26 generations (2 years) on lactose-agar.

Figure 1 shows a variation in the freshly isolated cultures from 7b, which failed to curdle milk in 5 days, to 7k, which curdled milk promptly, forming nearly 1 per cent of acid in 48 hours. Two years' growth under uniform conditions reduced these differences materially. The weaker cultures changed little or not at all, but the more active ones lost much of their vigor; that is to say, long-continued growth under uniform conditions tended to reduce these cultures to a common level. It is not easy to restore this lost vigor. Repeated transfers in milk increased the activity of some of the cultures, but failed to bring the more active ones back to the rapid fermentation of the fresh cultures. It is probable that these differences are due to a variation in the vitality rather than to a variation in the particular function of forming acid from sugar. In these studies it was frequently observed that those cultures curdling milk tardily or not at all multiplied slowly and never attained the numbers reached by the cultures curdling milk in a short time. This is illustrated by Table 2, in which is given the acid formation and rate of multiplication of two cultures, one curdling milk in a short time and one failing to curdle milk in 24 hours. Flasks of milk were inoculated from fresh milk cultures and incubated at 30° C.

TABLE 2.—*Relative rate of multiplication and acid formation in milk.*

Hours from inoculation.	Slow acid former.		Rapid acid former.	
	Acidity.	Bacteria per cubic centimeter.	Acidity.	Bacteria per cubic centimeter.
	Per cent.		*Per cent.*	
0	0.216	357,000	0.220	350,000
3	.216	586.000	.225	650,000
6	.225	1,690,000	.225	2,900,000
9	.225	16,900,000	.225	46,000.000
12	.230	59,500,000	.261	157,000,000
24	.306	710,000,000	.900	1,830,000,000

It will be observed that in a general way the acidity in each case is proportioned to the number of cells present. This is in accordance with the observation of Rahn,[10] who calculated the amount of acid formed in relation to the number of cells in the culture and found that this ratio was constant, although when only a small number of bacteria were present the amount of acid was so small that it could not be measured by ordinary methods. Schierbeck,[11] who studied this form of variation in the lactic-acid bacteria, found that by replating and making subcultures new cultures could be obtained, some of which followed the active fermentation of the original, while others were slow acid formers. In some of these cultures the rate of acid formation could not be varied by subsequent plating and selection, but cultures in which the ability to ferment lactose rapidly seemed to be fixed could be changed to slow fermenters by growing them in milk containing a small amount of carbolic acid. Buchanan and Truax [12] attempted to fix strains of the lactic-acid bacteria by selection and transfer from tubes of lactose broth showing wide differences in acidity. They failed entirely and concluded that "impressed variations do not appear to be heritable." It seems propable that they were unable to fix these variations because they were working, not with variations in a function, but with the rate of multiplication, something which may be controlled by an endless chain of circumstances. For the same reasons this characteristic can not be successfully used as a basis for classification.

GROWTH IN BROTH.

The growth in a medium of this nature should be considered as the expression of certain peculiarities not evident on superficial examination. A cloudiness or turbidity is, with the lactic-acid bacteria, an evidence of rapid growth, and it is governed more by external conditions than by the nature of the culture. Cultures which remain clear in nonsaccharine broth may be cloudy when certain sugars are added, and others may show cloudiness when dibasic potassium phosphate is added, but not in its absence. Profuse cloudiness is usually followed by a clearing and the accumulation of a sediment coinciding with the checking of the growth by increasing acidity. Some few cultures, however, never show turbidity, and the broth remains perfectly clear with no evidences of growth, although a high acidity is produced. This is perhaps due to the tendency to form tangled chains possessing in the aggregate a specific gravity greater than the broth. Müller[18] states that a clouded bouillon is associated with the formation of single cells or pairs, while a clear bouillon is coordinated with the formation of long chains. In his work he found that the cultures that never clouded the bouillon were the "Galt Stamme" found associated with yellow mammitis. When the failure to cloud the broth is fixed and constant it may be of some assistance in classification.

REDUCTION OF NITRATES.

The reduction of nitrates to nitrites was determined by growth in the following medium for 7 days at 30° C.

Peptone	gram	1.0
Potassium nitrate	gram	0.2
Water (distilled)	c. c.	1,000

Of the 147 cultures tested for the reduction of nitrates, 17 gave a positive reaction. All of these were differentiated from the typical lactic-acid bacteria by one or more coordinated characters. Twelve were of the liquefying tetrad group. Three (6fl, 7aa, and 7ak), were gas formers, and 7ak was in addition a bacillus larger than the lactic type and grew readily on solid media. One (7cc) resembled the lactic type in morphology but the cells were larger, and in addition to liquefying gelatin and giving an abundant growth on agar it made milk slimy. Culture 7dw was a small micrococcus.

None of the cultures belonging to Group I gave any evidence of growth in this medium. It is therefore of no value in making subdivisions of this group, but may be a convenient means for the detection of cultures resembling the type in many features but differing in certain salient points.

REDUCTION OF NEUTRAL RED.

In making this test the following medium was used:

Broth (neutral)	c. c.	1,000
Dextrose	grams	5
One-half per cent solution Grübler's neutral red	c. c.	10

The neutral broth was made as follows:

Beef extract	grams	4
Peptone	grams	10
Water	c. c.	1,000

The tubes were examined after incubating at 30° C. for 7 days in an anaerobic jar from which the oxygen was exhausted by absorption with pyrogallic acid. Gordon[14] considers this test of diagnostic value. It has, however, the disadvantage of not always giving definite results, although with nearly all cultures the reduction was either nil or very evident. Of the 36 cultures reducing neutral red, a large proportion ferment the more resistant test substances, such as saccharose, glycerin, mannite, and raffinose, and 7, or 19 per cent of the whole, liquefy gelatin. None of those liquefying gelatin ferment raffinose, while of the 29 nonliquefying cultures reducing neutral red 75 per cent ferment raffinose. There is a correlation between the reduction of neutral red, the liquefaction of gelatin, and the fermentation of saccharose, glycerin, and mannite in one group and between neutral red, saccharose, glycerin, mannite, raffinose, and inulin in another. These correlations are evident in figure 6. The faculty of reducing neutral red seems to be usually coordinated with other reactions and is therefore of some value in differentiating cultures.

LIQUEFACTION OF GELATIN.

The value of this test is too generally recognized to need discussion. In our work we have used Clark and Gage's method of reducing the rate of liquefaction to mathematical terms, ignoring the appearance of the culture. The gelatin tubes were inoculated by spreading a few drops of a fluid culture on the surface of the medium. The line of the surface was marked on narrow strips of paper pasted on opposite sides of the tube, and the cultures were incubated at 18° to 20° C. At the end of 30 days the amount of liquefaction was measured and expressed as millimeters of liquefaction. The results of this test are tabulated in Table 3.

TABLE 3.—*The liquefaction of gelatin.*

Liquefaction......millimeters..	0	1 to 5	6 to 10	11 to 15	16 to 20	21 to 25	Over 25
Number of cultures	108	3	10	10	2	3	2
Per cent of total	78.3	2.2	7.2	7.2	1.4	2.2	1.4

These results are platted in figure 3 to show the frequency of occurrence of certain arbitrary types.

This curve gives some indication of a division on the basis of gelatin liquefaction into three types, one failing to liquefy, one liquefying 6 to 15 millimeters, and one 20 to 25 millimeters. However, the total number of liquefying cultures was so small that it is safe to make a division into liquefiers and nonliquefiers only, and to depend on other tests for further division of the liquefiers. Even the separation of the liquefiers from the nonliquefiers is not entirely reliable, as it is well known that this character is variable and under some conditions may be entirely lost.

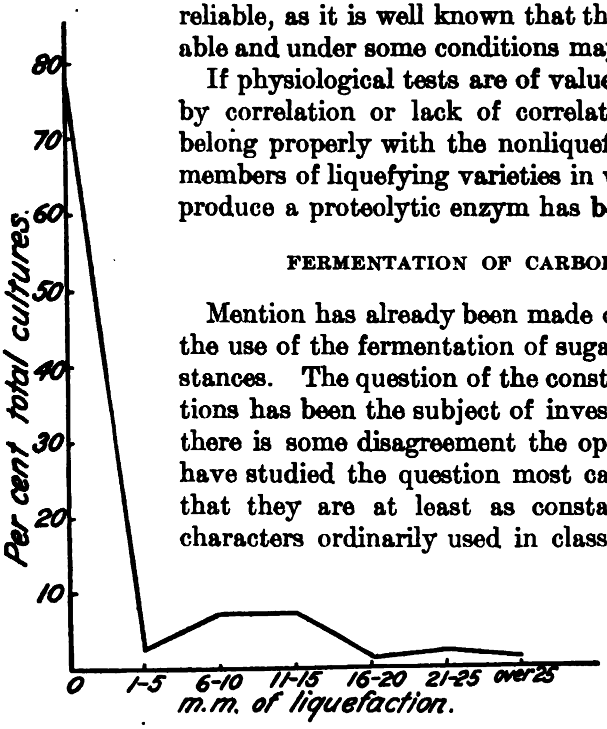

FIG. 3.—Frequency curve for gelatin liquefaction.

If physiological tests are of value they should show by correlation or lack of correlation which cultures belong properly with the nonliquefiers and which are members of liquefying varieties in which the ability to produce a proteolytic enzym has been lost.

FERMENTATION OF CARBOHYDRATES.

Mention has already been made of the objections to the use of the fermentation of sugars and similar substances. The question of the constancy of these reactions has been the subject of investigation, and while there is some disagreement the opinion of those who have studied the question most carefully seems to be that they are at least as constant as any of the characters ordinarily used in classification. Twort,[15] working with gas-forming cultures, was able to induce acid formation from sugars which the organism originally did not ferment by repeated transfers in a medium in which this sugar was the only carbohydrate furnished. Each transfer was held 14 days to allow the cells to work on the sugar after other sources of food had been exhausted. Ritchie[16] concluded that while cultures of *Bacillus coli* tested at different times gave constant fermentation reactions, the streptococci were inconstant. Gordon[17] tested the constancy of 11 cultures by passing them through mice. One culture lost ability to reduce neutral red and one gained ability to ferment salicin. All others remained unchanged. In all of this work the fermentative ability was determined by growing the organism in broth, with the addition of the test substance and litmus, and the change of the litmus from blue was taken as a positive reaction. A slight change in the reaction of the medium may change litmus from blue to red, and this acidity may be formed from some substance other than the sugar. The reduction of the litmus is certainly not an indication of the fermentation of the test substance. The work of MacConkey[18] indicates that under natural conditions these reactions are constant and of value in differentiation. Among the cultures examined were 15 cultures of *B. typhosus* varying from one freshly isolated to one grown 16 years on artificial media. These gave identical fermentation reactions when tested with various carbohydrates.

In another paper the same investigator states that the fermentative reactions of *B. coli* remained unchanged after a long exposure to unfavorable conditions. He expresses the opinion that one group is not derived from another by the loss of characters.

Harding,[19] working with *Pseudomonas campestris*, an organism pathogenic to certain plants, obtained somewhat similar results. Of the four substances used for fermentation tests this organism attacked only one, but this and all other physiological tests employed were identical for the 44 cultures collected from various parts of the country.

In our own work no systematic investigation was undertaken to determine the constancy of the fermentation reactions, but all our observations tend to prove that the property of forming acid from carbohydrates and similar substances is not easily lost or acquired. One culture showing no evidence of ability to ferment saccharose was carried for 100 generations, or a period of about one year, on a saccharose-agar. At the end of this period the culture still showed no fermentation of saccharose and the lactose fermentation remained unchanged.

In no case did any of our cultures show any change in fermentative ability on repeated tests. It not infrequently happens that a culture failing entirely to give an acid reaction on the first test showed an active fermentation when the test was repeated, but this was evidently due to a failure of the inoculation rather than to a change in the organism. Many of the cultures grew so poorly on artificial media that they were propagated with difficulty and transfers frequently failed to grow. A large proportion of the cultures were subjected to these tests two or three times, some of them at intervals of several months. The second test almost always agreed with the first not only in the presence or absence of fermentation but also in the amount of acid formed. This is illustrated by Table 4, which contains results on the fermentation of lactose. These figures were picked at random.

TABLE 4.—*Showing constancy of fermentation of lactose.*

Test.	Acidity of broth expressed as per cent of lactic acid.										
First.......	0.112	0.171	0.216	0.387	0.288	0.000	0.180	0.306	0.153	0.108	0.252
Second.....	.117	.261	.171	.306	.225	.144	.261	.288	.135	.099	.243

With some of the test substances the reaction was always very positive; that is, the reaction remained unchanged or a considerable acidity was developed. This was especially noticeable with saccharose, mannite, and raffinose. With others, particularly with glycerin, the acid was developed slowly and in such small quantities that it was sometimes difficult to determine if there was a real fermentation or a slight change in the reaction which was independent of the test substance. In doubtful cases a retest usually gave definite results.

It is not to be expected that a character of this kind would be absolutely fixed. Indeed, the fact that one culture attacks a certain sugar while similar cultures do not is evidence that this function is or has been a variable one. There is, however, no evidence to show that the tendency toward variation in fermentation is any greater than in any other character used as a basis of classification. The greater difficulty comes in the interpretation of the results. The objection that the number of varieties obtained is limited only by the number of test substances used is valid only when an absolute separation is made on each individual reaction. The usual botanical scheme of dichotomous separation when applied to the classification of bacteria on the basis of fermentation tests leads only to confusion and the rejection of the system. In the card arranged for the classification of bacteria by a committee of the Society of American Bacteriologists, dextrose, saccharose, lactose, starch, and glycerin are used as test substances, and cultures are separated in the usual way on the fermentation of or failure to ferment any one substance. By the use of these test substances and similar methods we could separate our nonliquefying cultures into five varieties. But if it is proper to separate cultures on the basis of the fermentation of dextrose, saccharose, or lactose we can use also raffinose and galactose, and if glycerin is allowable mannite can not be excluded, while inulin may be as useful as starch. Adding these test substances and following the same principles of division, we obtain no less than 14 varieties, and even these are not stable, because the introduction of a new test substance would probably subdivide them still more minutely.

Gordon [10] was the first to make an extensive use of the fermentation tests. These tests were also used on an extensive scale by Andrewes and Gordon [20] and by Houston.[21] This work shows the possibilites of arranging a large number of cultures in groups around type sets of reactions. Not all of the cultures in each group agreed perfectly with the type. Some failed in one reaction, while others possessed some character not common to the entire group. MacConkey,[18] using similar methods in a study of gas-forming bacteria from milk, was able to separate 112 cultures into 17 groups, and even these groups were sometimes separated by minor differences only.

On the basis of the individual reactions it was possible to separate these cultures into 64 varieties. This work was continued and placed on more scientific footing by Andrewes and Horder,[22] and especially by Winslow and Rogers, [23],[24] who applied the principles of biometry to the study of bacteria. In this way has been supplied a method of utilizing the physiological tests in such a way that bacteria may be collected in natural groups. In tabulating the characters of a large number of cultures, frequency of occurrence of those with certain common characters indicates the type, while the cultures varying from these types occur in smaller numbers and form the connecting links between the types. This represents the state of affairs in nature, while a description based by the ordinary method on the characters of a single culture may or may not agree with the type.

In our fermentation tests we have followed Winslow in determining the acidity rather than the mere fact of fermentation or nonfermentation. This is more exact and sometimes gives additional information of value in separating cultures. The medium was made as follows:

	Per cent.
Beef extract	0.4
Peptone	1.0
Dibasic potassium phosphate	.5
Test substance	2.0

The use of dibasic potassium phosphate is of advantage in that it serves to neutralize the acid and thus permits a more active growth and higher acid formation. The acid phosphate formed evidently checks the growth when a certain concentration is reached. The neutralization of culture media by this means is discussed by Henderson and Webster.[25]

The cultures were incubated 7 days at 30° C., with the exception of glycerin, which on account of the slow fermentation was held 14 days, and were titrated while cold against twentieth-normal sodium hydrate with phenolphthalein as an indicator. The result of the titration is expressed as per cent of lactic acid. Gas formation was determined by using an inverted inner tube in the dextrose broth. The results of the fermentation tests are given in detail in Table 1 and are recapitulated in Tables 5 and 6. The results shown in the two latter tables are given graphically in figures 4 and 5, in which the frequency of occurrence of cultures forming certain arbitrary amounts of acid is platted.

TABLE 5.—*Fermentation of test substances by liquefying cultures.*

Test substance.	Per cent of lactic acid.														
	Below 0.100.	0.101–0.150.	0.151–0.200.	0.201–0.250.	0.251–0.300.	0.301–0.350.	0.351–0.400.	0.401–0.450.	0.451–0.500.	0.501–0.550.	0.551–0.600.	0.601–0.650.	0.651–0.700.	Above 0.700.	Total cultures.
Dextrose:															
Number of cultures	1	4	5	12	1	0	3	1	0	1	0	0	1	0	29
Per cent of total...	3.45	13.8	17.2	41.4	3.45	0	10.3	3.45	0	3.45	0	0	3.45	0	.....
Lactose:															
Number of cultures	0	12	11	4	2	3	1	....	....	....	....	....	....	....	33
Per cent of total...	0	36.4	33.3	12.1	6.0	9.1	3.0	....	....	....	....	....	....	....	.....
Saccharose:															
Number of cultures	21	1	3	0	5	1	2	....	....	....	....	....	....	....	33
Per cent of total...	63.6	3.0	9.1	0	15.1	3.0	6.1	....	....	....	....	....	....	....	.....
Glycerin:															
Number of cultures	25	2	1	4	0	1	....	....	....	....	....	....	....	....	33
Per cent of total...	75.8	6.1	3.0	12.1	0	3.0	....	....	....	....	....	....	....	....	.....
Mannite:															
Number of cultures	22	1	2	3	3	0	1	1	....	....	....	....	....	....	33
Per cent of total...	66.7	3.0	6.1	9.1	9.1	0	3.0	3.0	....	....	....	....	....	....	.....
Galactose:															
Number of cultures	17	4	5	3	2	0	1	....	....	....	....	....	....	....	32
Per cent of total...	53.1	12.5	15.6	9.4	6.3	0	3.1	....	....	....	....	....	....	....	.....
Raffinose............															
Number of cultures	31	....	....	....	....	....	....	....	....	....	....	....	....	....	31
Per cent of total...	100	....	....	....	....	....	....	....	....	....	....	....	....	....	.....
Inulin:															
Number of cultures	22	0	0	0	0	0	1	....	....	....	....	....	....	....	23
Per cent of total...	95.6	0	0	0	0	0	4.4	....	....	....	....	....	....	....	.....

TABLE 6.—*Fermentation of test substances by nonliquefying cultures.*

Test substance.	Per cent of lactic acid.														
	Below 0.100.	0.101–0.150.	0.151–0.200.	0.201–0.250.	0.251–0.300.	0.301–0.350.	0.351–0.400.	0.401–0.450.	0.451–0.500.	0.501–0.550.	0.551–0.600.	0.601–0.650.	0.651–0.700.	Above 0.700.	Total cultures.
Dextrose:															
Number of cultures	1	0	2	4	10	12	30	13	10	12	11	5	3	3	116
Per cent of total...	0.9	0	1.7	3.4	8.6	10.3	25.9	11.2	8.6	10.3	9.5	4.3	2.6	2.6	.....
Lactose:															
Number of cultures	3	5	5	8	16	17	30	31	1	0	0	1	....	....	117
Per cent of total...	2.6	4.3	4.3	6.8	13.7	14.5	25.6	26.5	0.8	0	0	0.8	....	....	.....
Saccharose:															
Number of cultures	75	0	0	1	2	1	3	8	7	15	3	1	1	....	117
Per cent of total...	64.1	0	0	0.8	1.7	0.8	2.6	6.8	5.9	12.8	2.6	0.8	0.8	....	.....
Glycerin:															
Number of cultures	93	2	12	7	4	1	....	....	....	....	....	....	....	....	119
Per cent of total...	78.2	1.7	16.8	5.9	3.4	0.8	....	....	....	....	....	....	....	....	.....
Mannite:															
Number of cultures	78	1	0	3	4	4	3	0	1	11	11	....	....	....	116
Per cent of total...	67.2	0.9	0	2.6	3.5	3.5	2.6	0	0.9	9.5	9.5	....	....	....	.....
Galactose:															
Number of cultures	8	5	8	19	28	20	16	11	1	1	1	....	....	....	118
Per cent of total...	6.8	4.2	6.8	16.1	23.7	16.9	13.6	9.3	0.8	0.8	0.8	....	....	....	.....
Raffinose:															
Number of cultures	90	0	1	1	0	0	0	1	1	0	1	12	7	1	114
Per cent of total...	78.9	0	0.9	0.9	0	0	0	0.9	0.9	0	0.9	10.5	6.1	0.9	.....
Inulin:															
Number of cultures	101	0	0	2	9	5	0	....	....	....	....	....	....	....	117
Per cent of total...	86.3	0	0	1.7	7.7	4.3	....	....	....	....	....	....	....	....	.....

We have reckoned any acidity of below 0.1 per cent as no fermentation, although this may be an arbitrary distinction.

In the work by Winslow previously cited the frequency curves usually showed three modes. In his work, however, a larger number of cultures selected from various sources was used, while ours came from milk only. Our curves usually show only two modes, one at the point of no fermentation and one at a point of acidity varying with the different test substances. There are, however, certain differences in the curves of the liquefiers and the nonliquefiers. The dextrose curve for the liquefiers shows that a large proportion form 0.2 to 0.25 per cent of acid, with a smaller number at 0.35 to 0.4, while with the nonliquefiers there is a high point at 0.35 to 0.4 per cent and possibly a second mode at 0.5 to 0.6.

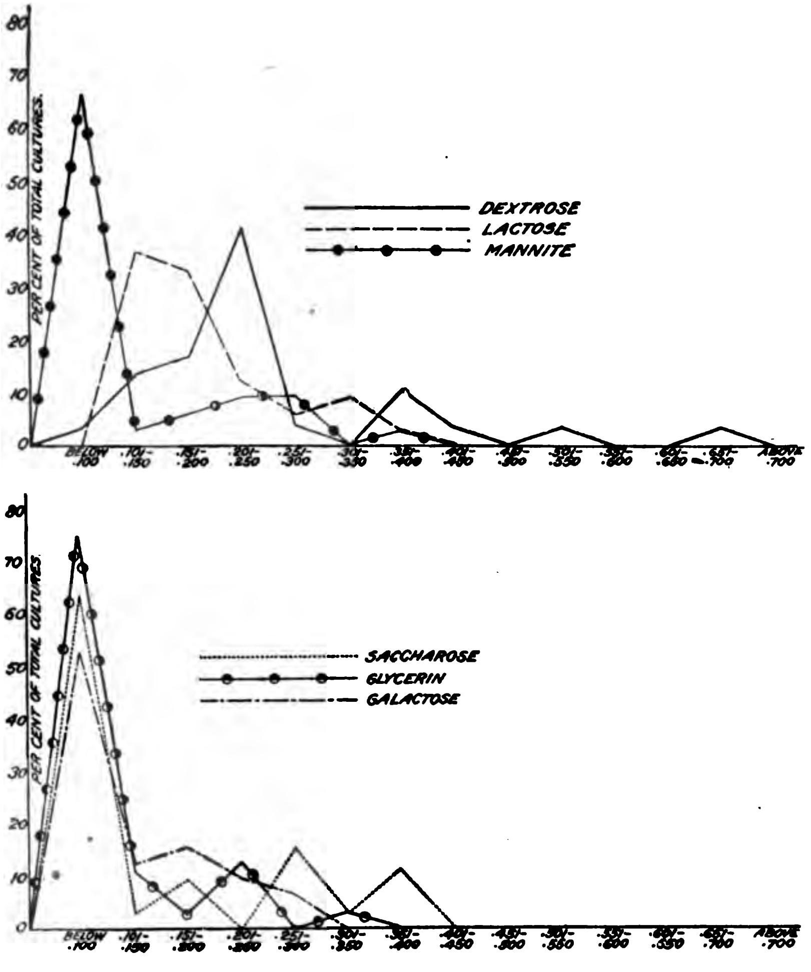

FIG. 4.—Frequency curves for acid formation by the liquefying cultures.

With the liquefiers the other test substances show two modes only. Raffinose was not fermented at all, and only one culture formed acid from inulin.

The number of liquefying cultures was too small to make many deductions therefrom, but it is easy to separate these cultures into two distinct groups. One of these forms a small amount (0.1 to 0.3 per cent) of acid from dextrose, and is a micrococcus usually appearing in tetrads. The effect on milk is weak, and the curdling, which is slow, is probably due more to the action of a rennet than to the production of acid. This group, as represented by these cultures, is undoubtedly heterogeneous, and by the application of these methods to a larger number of cultures would be split up in distinct subgroups. The second group of liquefiers is interesting in that it evidently is a variation from the typical nonliquefying lactic-acid organism. In its morphology it is identical with the ordinary type, but differs from it not only in the liquefaction of gelatin, but also in usually fermenting glycerin. Its action on milk is characteristic.

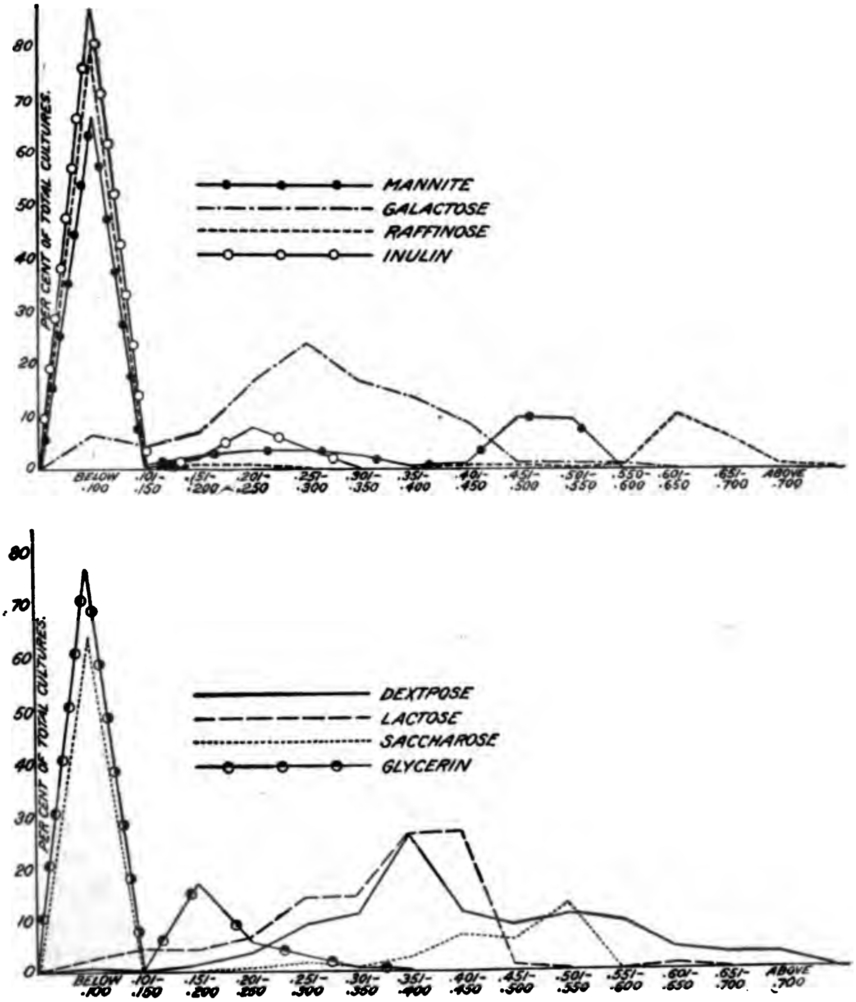

FIG. 5.—Frequency curves for acid formation by the nonliquefying cultures.

The milk is curdled promptly with a firm acid curd; digestion begins at once and almost always causes a separation of curd from the whey down the side of the tube.

In the nonliquefying group there are with all the test substances only two distinct modes in the curves with the possible exception of mannite. In this case there are three modes, one below 0.1 per cent, one between 0.1 and 0.35, and another between 0.45 and 0.5.

Reference to Table 1 shows that of the 8 cultures belonging to the group falling between 0.1 and 0.35 per cent, 2 were gas formers and 1 made milk slimy, while the other 5 apparently did not differ from those forming a high acidity or failing entirely to ferment this substance.

In arranging these reactions on the basis of their correlations, one of the formulas for the expression of correlation, as, for instance, that of Yule, may be used, but for this particular work the determination of the coefficient of correlation is not necessary. Even a casual examination of Table 1 shows that the nonliquefiers may be separated into two groups, in one of which the fermentation is usually limited to dextrose, lactose, and galactose, with an occasional culture fermenting saccharose or mannite. A second group may be formed of cultures in which the fermentative ability is distinctly higher. These groups are illustrated by figure 6, in which each culture is placed in one of four groups and arranged on the positive or negative side of a dividing line, as the case may be, in each of the salient characters.

The division of the nonliquefiers is not an arbitrary one, as the distinction between the two groups is marked. Not only is there a general lack of fermentative ability in Group A, but there is no correlation in the few cases of fermentation of the more difficultly fermentable substances. The fermentation of saccharose is no indication that the culture will ferment mannite. On the other hand, in Group B more of the test substances are fermented and there is a high correlation between certain activities. The fermentation of raffinose is usually correlated with the fermentation of saccharose, mannite, and glycerin, and to a lesser degree with inulin. The high fermentation is also correlated with the reduction of neutral red.

In making up these groups it was found that 6 cultures (6fl, 7aa, 7ak, 7cq, 7dw, and 13u) did not belong in this collection, and they were not included in the table. It will also be noticed that 7ci, 7cg, and 7dm are in a transition stage between Groups A and B, either through the loss of properties formerly possessed or the acquisition of new ones. In morphology and general culture characters all of the numbers of this group agree with the typical lactic culture. It should be stated that we obtained all of the cultures of Group B from one locality, Albert Lea, Minn., although not from one sample. However, in the course of another investigation a large number of cultures which could be properly placed in this group have been isolated from Washington milk, indicating that it is widely distrib-

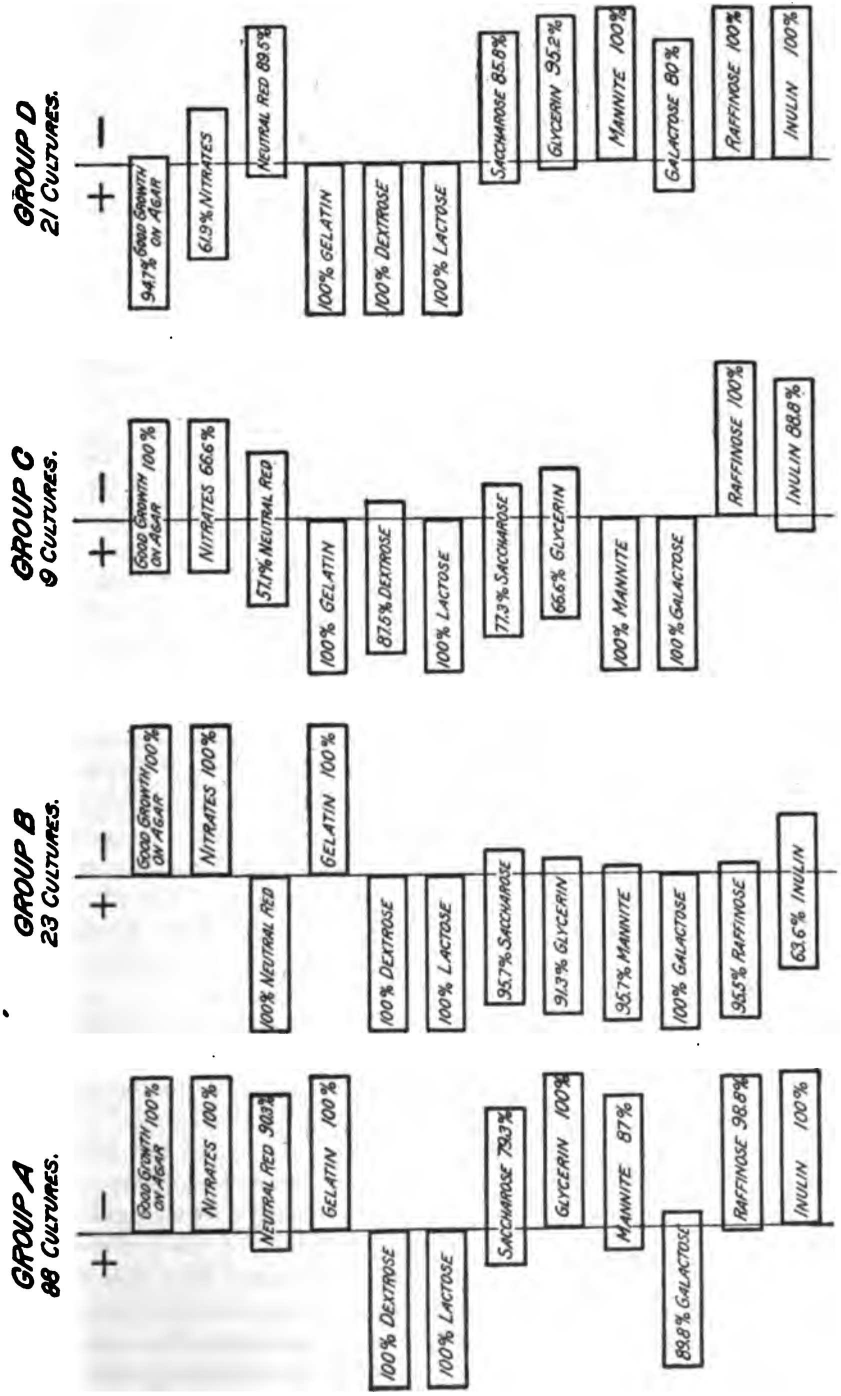

FIG. 6.—Grouping of cultures and distribution of characters in groups.

uted, although it does not occur in so large numbers as the Group A type. While the number of cultures included in Group C is too small to permit many positive deductions, it is evident that it represents a type quite distinct from A and B, from which it is differentiated not only by the liquefaction of gelatin but also by the correlated functions of the fermentation of mannite and glycerin and the failure to ferment raffinose and inulin. These 9 cultures include 3 differing somewhat from the others morphologically, and it is probable that a larger collection would allow a deeper and more positive separation. Group D is made up of cultures which, while they are of common occurrence in milk, have such a low fermentative ability that they probably take little part in the normal souring of milk.

CONCLUSIONS.

The stability of the fermentation tests is made evident not only by the constancy of the reactions on repeated tests, but also by the marked correlation between different fermentative activities and between the fermentations and other characters.

The usefulness of these tests is only apparent when by means of biometrical methods the correlations are established and the cultures are arranged in groups possessing certain characters in common, but in which minor variations from the type are not excluded.

The test substances used can not be determined arbitrarily. It is probable that it will be desirable to vary the test substances used with different groups of bacteria. We have found raffinose and glycerin and the gelatin test especially valuable, while saccharose, which has long been used for differential tests, has much less value. All of the groups have many cultures fermenting this sugar, and there is little correlation with other reactions. While the determination of the fermentation of raffinose or glycerin gives one a good idea of the group in which the culture should be placed, the knowledge that a culture ferments or fails to ferment saccharose is of little assistance.

It should be remembered that these cultures were all selected on the basis of the possession of a single positive character, the fermentation of lactose. If the collection had been made on a broader basis, it is highly probable that the cultures would have formed other groups around types distinct from those we have found but related to them by certain common characters and by transition forms.

The results recorded in this paper are too meager to warrant any attempt at fixing names or establishing the place of the lactic-acid bacteria in the bacteriological system, but we believe that this work indicates that future efforts in the direction of systematic bacteriology should be toward the determination of those characters that are significant and enduring rather than in fruitless controversy over the priority or stability of some name based on descriptions so undeterminative that they convey no meaning.

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BUREAU OF ANIMAL INDUSTRY.—BULLETIN 155.
A. D. MELVIN, CHIEF OF BUREAU.

THE INFLUENCE OF THE STAGE OF LACTATION ON THE COMPOSITION AND PROPERTIES OF MILK.

BY

C. H. ECKLES,
Professor of Dairy Husbandry, University of Missouri,
AND
ROSCOE H. SHAW,
Chemist, Dairy Division, Bureau of Animal Industry.

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ANIMAL INDUSTRY,
Washington, D. C., June 29, 1912.

SIR: I have the honor to transmit, and to recommend for publication in the bulletin series of this bureau, the accompanying manuscript entitled "The Influence of the Stage of Lactation on the Composition and Properties of Milk," by Prof. C. H. Eckles, of the Missouri Agricultural Experiment Station, and Mr. Roscoe H. Shaw, of the Dairy Division of this bureau. The experimental work herein described forms a part of the investigations concerning milk secretion which are being conducted at the Missouri station in cooperation with this bureau.

There is a considerable amount of data available bearing upon the lactation period of cows and the effects on the composition of the milk, but as a rule such investigations have been confined to a single constituent of the milk, usually the fat. No record could be found of any investigation with controlled animals where all or even a majority of the milk constituents have been studied during a complete lactation period. Accordingly it was deemed advisable to undertake the present work so as to cover this point satisfactorily. The cooperative work mentioned has been in progress for about six years. Investigations regarding the influence of other factors concerning milk secretion are also under way and will be reported later.

The authors desire to acknowledge their indebtedness to Messrs. A. E. Perkins, J. O. Halverson, and J. C. Payne, formerly of the Dairy Division, for assistance rendered in compiling the data in this bulletin.

Respectfully,

A. D. MELVIN,
Chief of Bureau.

Hon. JAMES WILSON,
Secretary of Agriculture.

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THE INFLUENCE OF THE STAGE OF LACTATION ON THE COMPOSITION AND PROPERTIES OF MILK.

INTRODUCTION.

It is a well-known fact that although the same constituents are always present in milk, the relative amounts of each are subject to constant variation. These variations in composition are known to be influenced by a number of causes, among which are (1) the breed of the animal, (2) the individuality, (3) to some extent the feed, (4) the interval between milkings, (5) the various stages in the period of lactation, (6) more or less by the health of the animal and by temperature and weather conditions. It is also known that the fore milk and the milk last drawn differ in composition, and that some variations occur between morning and evening milkings. A large number of observations are recorded regarding these variations and their causes, mostly, however, in connection with the fat alone. The data regarding certain of these factors are consistent and conclusive, but concerning others they are conflicting and insufficient to justify general conclusions. The main criticisms to be made regarding the large amount of data that has been published along these lines is that in most cases only the per cent of fat was taken into account and that the animals supplying the samples were not properly selected and controlled.

In 1906 an agreement was entered into between the Missouri Experiment Station and the Dairy Division, Bureau of Animal Industry, United States Department of Agriculture, for a series of investigations, the main object of which was to be a further study of the factors influencing the composition and properties of normal milk. In beginning such a line of investigation it was decided that it would be necessary to repeat much of the work that had been done in the past, but under more carefully controlled conditions, in order that results might be more definite. There are a number of questions that have to be considered in planning all such investigations regarding the selection of suitable animals to furnish the samples. Among the questions that always arise in this connection are the three following: The effect of the stage of lactation, the influence of the breed, and the individual variations. The logical plan in beginning such a series of investigations as was contemplated seemed to be first to supply further data on the effect of the three factors mentioned. The data at the same time would serve as a basis for the planning of future work regarding the influence of other factors.

Since the various stages in the period of lactation represent a factor always to be taken into account and one known to have an important bearing on the composition of milk, plans were made to begin these investigations with this as the first main objective point. The plans were so arranged that the same data would also add to our knowledge regarding the influence of the other two factors, i. e., the breed and individuality of the animal.

In this publication the influence of the stage of lactation alone is considered. The data regarding the influence of breed and individuality of the animal are to be published in the near future.

PREVIOUS INVESTIGATIONS.

There is a mass of data available which has a connection either near or remote with the influence of the stage of lactation on the chemical composition of milk. The advent of the Babcock test in 1890, which offered a rapid and simple method for the determination of fat, lent a stimulus to such investigations. As a whole the investigations along this line which have been published have been limited to a single constituent of milk, usually the fat. In but few cases has any attempt been made to eliminate the influence of the feed of the animals, and there is no record of any investigation on controlled animals where all or even a majority of the milk constituents have been studied during an entire lactation period.

No purpose would be served by giving a complete list of the works published on this subject. From a large number of references the following have been selected as representing the more important investigations having to do with the influence of the stage of the lactation period on the chemical composition of milk:

Schrodt and Henzold [1] in 1888–1891 conducted a series of investigations on the composition of butterfat and its variation as influenced by the period of lactation, feed, etc. The first investigation was conducted with mixed milk from a herd of 10 cows of Angler, Brietenburg, and Shorthorn-Dithmarschen breeds and with milk from an individual Angler cow. The second investigation was conducted with the mixed milk from a herd of 220 cows of Angler and Ayrshire breeds. The cows were not kept on a uniform ration. In both investigations they were stall-fed in the winter and put out to pasture during the summer months. Samples were taken from the one Angler cow every day for the first 16 days after calving, then every

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[1] Schrodt, M., and Henzold, O. Untersuchungen von Butterfett. Die Landwirtschaftlichen Versuchs-Stationen. vol. 38, p. 349–371. Berlin, 1891. Vol. 40, p. 299–309. Berlin, 1892.

3 or 4 days till the end of the lactation period. The samples of herd milk in both investigations were taken twice weekly. The milk was skimmed, churned sour, the butter melted, and the clear fat filtered off. Determinations were made on the samples from the individual cow of volatile acids, iodin number, and the refractive index. On the mixed milk the same determinations were made and in addition the determination of the insoluble acids. In the case of the mixed milk the stage of the lactation period was found by averaging the lengths of the periods that the individual cows had been in lactation. In all of the investigations the course of the variation of the different constituents was practically the same through the lactation period. The following conclusions were reached:

> In the first milkings the percentage of volatile acids in the fat is very low, but it rises rapidly in the first few days to a maximum value. Then it remains stationary for about 2 months, after which it declines steadily until the close of the lactation period.
>
> The content of olein as shown by the iodin number constantly decreases during the lactation period.
>
> In the latter part of the lactation period the percentage of insoluble acids is higher than in the first part.
>
> As a rule the decrease in the volatile acids is accompanied by an increase in the refractive index.
>
> Apparently the composition of the butterfat bears a close relation to the stage of lactation, but none to changes from stall feeding to pasture feeding.

Klein and Kirsten [1] in 1901 and 1902 conducted an investigation on individual samples from five cows to find the effect of age of the cows and of the stage of lactation on the composition of the butterfat. The cows selected were of different ages. Three were old cows, aged respectively 13, 9, and 8 years. Two were 3-year-old cows. All of the cows were given the same feed, but the feed was not uniform throughout the lactation period. Samples were taken at intervals of approximately one month. The determinations included the Reichert-Meissl number, Koettstorfer number, Hehner number, Hubl number, and refractive index.[2] Curves were plotted from the results and the following variations due to the period of lactation shown:

> The Reichert-Meissl number showed a gradual decrease throughout the lactation period.
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> The Koettstorfer number followed approximately the same variations as the Reichert-Meissl number. In two cows it rose near the end of the period.
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> The curve for the Hehner number rose during the entire period. It showed variations which were in the opposite direction to those of the Reichert-Meissl number.

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[1] Klein, J., and Kirsten, Arthur. Untersuchung über die chemische Zusammensetzung des Milchfettes einzelner Kühe von verschiedenem Alter im Laufe einer Laktation. Milch Zeitung, vol. 31, no. 37, p. 577–578, Sept. 13; no. 38, p. 594–596, Sept. 20; no. 39, p. 611–613, Sept. 27. Leipsic, 1902.

[2] For the methods used in these determinations see footnote on page 22.

In general the Hubl number showed a rise with the period of lactation, but in 2 cows there was a decline near the end of the period. The authors ascribe this variation to a change in the feeding.

The refractive index showed the same variations as the Hubl number.

There were many minor variations which were thought by the authors to be due to difference in feeding.

Penny,[1] of the Delaware Agricultural Experiment Station, secured some data on the effect of the stage of lactation on the composition of milk from testing the large herd of a Delaware dairyman. Three series of tests were made, each series covering 5 consecutive days, the series being located along the course of lactation as follows: The first, 2½ months after calving; the second, 6½ months; and the third, 10½ months.

From these Prof. Penny concludes that the quantity of milk decreases more or less gradually, and the quality increases in nearly the same ratio, as the lactation period advances.

Hinchcliff[2] at Leipsic in 1901–2 conducted a careful investigation, which included among other factors the influence of the stage of lactation on the chemical composition of milk. His laboratory work is so thorough that it is to be regretted that the number of animals was so limited and his data concerning them so uncertain.

He studied the milk from 3 cows, one of these from the third week of the lactation period to the end and another from the seventh month of the lactation period to the end. Data concerning the condition of the third were lacking, but he states that she was apparently fresh when the study was commenced. The study of the third cow was also carried on to the end of the lactation period. He took samples from each milking for 5 or 6 successive days, which length of time he calls a period. These periods, with but few intervals, succeed each other during the whole lactation period. Analyses were made of each sample and averages calculated to represent the period. No attempt was made to feed the cows on a uniform ration, but a record was kept of the feed given them.

He found that the greatest variations were in the fat, followed by sugar, protein, and ash in the order mentioned. An increase or decrease in the fat content of the milk was usually accompanied by a similar change in the fat content of the milk solids, but by an opposite change in the percentage of protein and sugar in the milk solids. The ash content of the solids not fat was practically constant. Variations in the content of the solids not fat read inversely to the variations in the protein content. In general the percentages of fat, protein, and ash increased with the progress of lactation.

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[1] Penny, Charles Lyndall. Herd-testing. Delaware Agricultural Experiment Station, Tenth Annual Report, p. 159-197. Wilmington, 1898.

[2] Hinchcliff, Joseph Henry. Die täglichen Schwankungen im Gehalte der Kuhmilch an den einzelnen Bestandteilen im Verlaufe der Laktation. Mitteilungen des Landwirtschaftlichen Institutes der Universität Leipzig, No. 5, pp. 1-112. Berlin, 1904.

Swaving[1] in 1889–90 investigated the butterfat from cows in various provinces in Holland with a view of establishing the limits of the volatile fatty acids in butter in order to distinguish pure butter from butter substitutes. He took samples from the different provinces at regular intervals for a considerable period of time, and concludes that at the beginning of the lactation period the percentage of volatile fatty acids increases, but that it decreases as the period progresses.

Schellenberger,[2] in the University of Leipsic, made a study of the size of fat globules with reference to the different breeds and periods of lactation. His published tables gave figures in which he shows that the Jersey cow has the largest-sized globules and the Angler cow the smallest. He also shows that as the lactation period progresses the size of the globules decreases.

Hills,[3] of the Vermont station, studied the results of over 100 lactation periods of cows of many breeds, with diversified feed and in three geographical localities, namely, New York, Minnesota, and Vermont. His conclusions are given in a summary, in which he states:

> The average spring cow rapidly betters the quality of her milk, beginning about 5 months after calving; the summer cow starts in as early as the third month; while the fall cow maintains a fairly even quality throughout her lactation period, seldom improving it more than 5 per cent in fat content. The percentage of solids not fat also is more uniform month by month in the milk of the fall cow. The percentage of solids not fat in the milk of spring cows seems to lessen somewhat in the summer time.

The greatest monthly variation in the quality of the milk of 115 cows was 3.11 per cent fat; the least 0.33 per cent fat. The average variation was 1.26 per cent fat; the average monthly variation of spring cows was 1.62 per cent fat; of fall cows, 1.08 per cent fat; of summer cows, 1.25 per cent fat. Two-thirds of the Vermont and Minnesota herds gave thinnest milk during the first 2 months and two-thirds of the New York herds during the first 4 months. Ninety per cent of the Vermont and Minnesota cows gave their richest milk after the seventh month. Sixty per cent of the New York cows gave their richest milk before the eighth month.

Speir,[4] at Newton Farm, Glasgow, reviewed the records of about 400 cows that were included in the herds of members of a more or less local testing association, with a view of studying the changes in the percentage of fat as the lactation period advanced. His scheme was substantially as follows: The cows were divided into groups, each group representing the cows which had calved within a certain period, usually 2 weeks. The shortest fraction of the lactation period was 1 week and the longest period was 14 weeks. His figures show that the fat content was highest during the first week and lowest during the fourth week, after which a gradual increase was observed.

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[1] Swaving, A. J. Sättigungszahlen für die flüchtigen Fettsäuren der niederländischen Buttersorten. Die Landwirtschaftlichen Versuchs-Stationen, vol. 39, pp. 127–141. Berlin, 1891.

[2] Schellenberger, O. Ueber die Grosze und die Zahl der Fettkügelchen in der Milch von Kühen verschiedener Rassen. Milch Zeitung, vol. 22, No. 50, pp. 817–819. Bremen, Dec. 16, 1893.

[3] Hills, Joseph Lawrence. Variations in milk. Vermont Agricultural Experiment Station, Ninth Annual Report (1895), pp. 158–186. Montpelier, 1896. See p. 158.

[4] Speir, John. Milk records. Transactions of the Highland and Agricultural Society of Scotland, ser. 5, vol. 17, pp. 182–212. Edinburgh, 1905.

Dean[1] tested 6 cows for 273 days at the Ontario experiment station. He divided this time into 3 periods of 91 days each, and averaged the percentage of fat in each period. He states that he found no such increase in percentage of butterfat in milk as is generally accredited to the influence of the period of lactation, there being an increase of but 0.17 per cent in the second period and 0.46 per cent in the third over that of the first period.

Cooke,[2] after studying the complete records of the Vermont station, which covered a period of several years, gives these conclusions regarding the influence of the stage of lactation on the composition of milk:

> All cows shrink in quantity of milk as they get farther from calving. If they are farrow, this shrinkage in quantity is accompanied by almost no change in quality, even until they go dry, provided they are still farrow. If they are in calf, the milk increases in quality as it decreases in quantity; this increase is slight—but one-twentieth during the first 6 months after calving—but becomes quite pronounced just before the cow goes dry.
>
> Cows that calve in the spring give on the average more milk during the first 3 months after calving than those that calve in the fall. For the seventh, eighth, and ninth months this is reversed. Fall cows show smaller variations in the quality of the milk than cows that calve in the spring. The milk of a cow for the first few days or weeks after calving is very variable in quality. On the average, it is thinnest just after calving, becomes slightly richer during the next 2 weeks, and then holds almost uniform in quality for the next 4 or 5 months.
>
> Just after calving the milk is poorer in fat and in solids not fat than just before the cow went dry. The average drop in fat is 1.13 per cent, the greatest change being 2.35 per cent and the least 0.49 per cent. The average change in solids not fat is a fall of 0.47 per cent, with variations from a decrease of 1.94 per cent to an increase of 0.42 per cent.

Pingree,[3] of Pennsylvania, has published some literature on this subject. The extent of the data on which his deductions are based may be indicated by using the author's own language:

> In cooperation with the Dairy Breeders' Association and in connection with the advanced registration of dairy cows, the station has made the official examination of about 1,500 milk samples representing the product of 128 cows from 11 herds.

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[1] Dean, Henry Hoshel. Record of our dairy herd. Ontario Agricultural College and Experimental Farm, Seventeenth Annual Report (1891), pp. 173-175. Toronto, 1892.

[2] Cooke, Wells Woodbridge. Variations in quantity and quality of milk. Vermont Agricultural Experiment Station, Sixth Annual Report (1892), pp. 90-119. Burlington, 1893. See p. 90.

[3] Pingree, M. H. Report of the composition of milk from herds competing for advanced registration. Pennsylvania Agricultural Experiment Station, Annual Report (1905-1906), part 2, pp. 54-93. Harrisburg, 1906. See p. 54.

The author's conclusions in summary may also be given in his own words:

> The percentages of butterfat showed, on the average, a tendency to increase throughout the entire lactation period, but the increase was most marked during the first 5 months and the last month. The percentage of solids not fat decreased somewhat as the lactation period advanced.

Linfield[1] prepared 2 tables from Utah data which are calculated to indicate in some measure the character of changes in the composition of milk that are due to the advance of the period of lactation. Twelve cows were used in this investigation. They were nearly all ordinary grade animals. The lactation season in each case was divided into periods of 4 weeks each, beginning 3 weeks after calving. The author's summary is substantially as follows:

> The decrease in milk and fat yield is fairly constant and averages about 9 per cent decrease each period of 4 weeks.
>
> The yield of butter fat does not decrease as rapidly as the milk, due to an increase in the percentage of fat in the milk as the period of lactation advances.
>
> The percentage of fat in the milk decreased slightly for the second period and then gradually increased till the ninth month. For the ninth, tenth, and eleventh months the test remained practically stationary and increased again for the twelfth month.
>
> On the average the cows gave the richest milk at the end of their lactation period. An examination of the yearly record shows that a few cows for 1 year gave poorer milk when they went dry than when fresh, but in no case where the average of 2 or more years was considered do the cows depart from the average result. With some the increase in per cent of fat was much greater than with others.

Farrington,[2] when chemist to the Illinois experiment station, conducted an investigation with 6 animals for the purpose of throwing light on the influence of the stage of lactation on the chemical composition of the milk. The investigation, which was conducted through an entire lactation period, consisted of daily determinations of the weight of the milk, percentage of fat, percentage of total solids, and percentage of solids not fat. The animals represented 3 breeds, namely, Jersey, Holstein-Friesian, and Shorthorn. The feeding varied considerably during the investigation. Prof. Farrington's conclusions in his summary are:

> The butter fat was the most changeable constituent of the milk. The percentage of solids not fat was quite uniform. Both were higher in the last part of the period of lactation than in the first, when the cows were fresh and the maximum quantity of milk was produced. This was especially true of the fat. As the activity of the milk glands gradually declines until the flow of milk ceases, the formation of the fat seems to hold out better than the other constituents of the milk. A gradual increase of the grain feed from 12 to 24 pounds a day per head, and the change from stable to pasture feed, each increased the yield of milk, but had very little, if any, effect on its quality.

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[1] Linfield, F. B. Experiments with dairy cows. Utah Agricultural Experiment Station Bul. 68. Logan, June, 1900.

[2] Farrington, Edward Holyoke. Variations in milk. Illinois Agricultural Experiment Station Bull. 24. Champaign, 1893.

Simon[1] in 1900 started an investigation of the effect of the stage of lactation on the proteids of milk. Two cows were used, one a Friesian and the other a grade of Simmental Dithmarschen strain. One of these cows was on a constant ration, but the feed of the other was changed several times. The lactation periods were prolonged owing to the fact that the cows did not become pregnant until late in the period. At the end of the first year the work was continued by Trunz.[2]

Analyses were made on samples from each milking during the colostrum period and afterwards on composite samples of one day's milk taken at weekly intervals. The analyses were confined to weight of milk, specific gravity, fat by Gerber's method, total solids, total nitrogen-containing substances, total proteids, casein, albumin and globulin, and residual nitrogen. The total nitrogen was determined by the Kjeldahl method. The total proteids were determined by precipitation with tannic-acid solution. The casein was determined by the Schlossman potash-alum method. The combined albumin and globulin were determined by precipitation with tannic-acid solution in the filtrate from which the casein had been removed. The residual nitrogen was determined in the filtrate from the total proteid determination by the Kjeldahl method.

In his conclusions Trunz stated that the milk production reached its highest point several weeks after calving and then sank slowly and regularly to the end of the lactation period. The specific gravity followed the opposite course. The total solids and fat content started high, then sank until the third or fourth month, when they remained approximately constant for a time, and then rose to the end of the lactation period.

Excluding the colostrum period, the total nitrogen content remained practically constant for 6 or 7 months. It then rose gradually until it almost doubled its average value at the end of the lactation period. The total proteid content followed closely the total nitrogen content. Excluding the colostrum period, the relation of the percentage of casein to the percentage of albumin and globulin showed no decided variation, though the ratio of casein was much higher in the case of one cow than with the other. The residual nitrogen was high in the colostrum period, but did not suffer any material change.

Hittcher,[3] in 1890–91, conducted a series of investigations on 16 purebred Holstein (Hollandischen) cows, lasting through an entire period of lactation. This was a continuation of the work of Dr.

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[1] Simon, Gustav. Beitrag zur Kenntniss der Eiweisskörper der Kuhmilch. Zeitschrift für Physiologische Chemie, vol. 33, No. 5/6, pp. 466–541. Strasburg, Oct. 31, 1901.

[2] Trunz, August. Über die Schwankungen der Eiweiszstoffe der Kuhmilch im Verlaufe einer Laktation. Zeitschrift für Physiologische Chemie, vol. 39, No. 5, pp. 390–395. Strasburg, Sept. 19, 1903.

[3] Hittcher, Karl. Untersuchung der Milch von sechszehn Kühen. Landwirthschaftlicher Jahrbucher, vol. 23, pp. 873–967. Berlin, 1894.

Fleischmann, the results of which were published in 1891,[1] with the difference that the investigations were begun at the beginning of lactation and not after lactation was already in progress.

Sixteen registered cows which calved at about the same time were selected for the tests. Except for minor differences, the cows were all given the same treatment and feed, but they were not kept under the same external conditions nor on the same feed during the entire period of lactation. In several cases where there was some change in conditions there was a noticeable change in the composition of the milk.

After each milking the milk was weighed and an average sample was taken. The specific gravity of this sample was taken with a standardized lactometer (Senkwaage) 3 hours or more after the milking, and the percentage of fat was determined by means of a De Laval lactocrit. From these results an average for each month was computed. From these averages the percentage of total solids and the specific gravity of the total solids were computed by means of Fleischmann's formula. Then from the above results were computed the percentage of solids not fat and the percentage of fat in the total solids. Tables were then made and curves plotted from these results. From these the following points were noted:

1. The fat content in 10 cows was higher at the end than at the beginning of lactation. In 3 of these the increase was slight. In 6 cows the fat content was lower at the end than at the beginning, and in 4 of these the decrease was quite noticeable. In the previous investigation the fat content had increased in all but 1 cow. This is partially accounted for by the fact that the previous year the investigation began after lactation was in progress. There were some irregularities in the fat curve which were easily accounted for by changes in feed, weather, etc.
2. The percentage of solids not fat decreased noticeably in the first weeks of lactation, then it usually made an even, slightly rising curve to the end.
3. The total solids decreased rapidly in the first weeks of lactation and rose rapidly in the last weeks. In general it followed the curve of the fat content.
4. The direction of the curve of the percentage of fat in the total solids is variable. It usually descends during the first weeks, then rises. In all cases there was a rise in the curve in September, due probably to changes in external conditions.
5. The total milk production decreased from first to last.
6. In every case where there was any considerable increase in milk production there was a decrease in she percentage of fat.

Gripenberg,[2] in 1889–1891, conducted a series of investigations to find the variation in the fat content of milk during the period of lactation. The cows used for the investigation were Holstein, Ayrshire, Angler, and native. The Holstein cows were fed a uniform ration throughout the year. Individual samples and composite samples from the cows of each breed were taken weekly and fat determinations made with a Fjord centrifuge. It was found that there was an increase in fat toward the close of the lactation period.

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[1] Fleischmann, Gustav Friedrich Wilhelm. Untersuchung der Milch von sechszehn Kühen. Berlin, 1891.

[2] Gripenberg, R. Redogörelse öfver verksamheten vid Mejeriafdelningen af Försöksstationen å Mustiala Institut 1892. Redogörelser för Landtbruksekonomiska försök å Mustiala Landtbruks-och Mejeriinstitut (1892) Landtbruksstyrelsens Meddelanden, No. 3, pp. 22–49. Helsingfors, 1894.

Högström[1] conducted a series of investigations extending over a period of 8 years to determine the changes in the composition of milk during the period of lactation. For the investigation he used 393 Ayrshire and native cows and obtained data from 822 lactation periods. Fat determinations by the Babcock method were made twice monthly during the period of lactation.

It was found that, if the colostrum period be omitted, the percentage of fat is high during the first month, but soon begins to decrease rapidly and continues to decrease until the third month, when it reaches its minimum value. From there on it increases gradually, reaching its maximum value at the close of lactation.

Hunziker[2] conducted an investigation with 3 animals for the purpose of studying the effect of the stage of lactation on the moisture content of butter. The breed of the animals is not stated. The ration, which excluded such feeds as would tend to influence the hard or soft fats, was uniform during the entire period of lactation. His determinations included the total proteids, the casein, the albumin, and the chemical constants of the fat.

His conclusions were as follows:

> The fresh milk drawn after calving contained as high as 13.5 per cent proteids with about equal portions of albumin and casein. At the end of the second day the per cent of albumin in the milk from all 3 cows had dropped to below 1 per cent. But both the per cent of albumin and that of casein were considerably above the normal, even at the fourteenth milking. Slight irregularities excepted, there was a rapid decrease in the per cent of albumin, casein, and total proteids during the first 7 days after calving, then a gradual decrease up to and including the second month, then the per cent remained fairly constant up to and including the fifth month. After that there was a gradual increase up to and including the eighth month, followed by a more rapid rise toward drying up.
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> The Reichert-Meissl number and the per cent of soluble fatty acids were highest at the beginning of the period of lactation; slight irregularities excepted, they decreased as the period of lactation advanced and were lowest toward the close of the period of lactation.
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> The insoluble fatty acids were lowest at the beginning, gradually increasing during, and were highest at the end of, the period of lactation.
>
> The fact that the Reichert-Meissl number, the soluble and the insoluble fatty acids, bear a definite relation to one another, shows clearly that the per cent of soluble and insoluble acids is affected by the period of lactation, and that the soluble acids decrease while the insoluble acids increase as the period of lactation advances.
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> The results concerning the iodin number are irregular and, considering the relatively small number of data, do not warrant the drawing of definite conclusions as to the effect of the period of lactation on the per cent of olein in butter.

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[1] Högström, K. A. Komjölkens fetthalt, dess normala växlingar och ärftlighet. Kungliga Landtbruks-Akademiens Handlingar och Tidskrift, vol. 45, No. 3/4, pp. 137-176. Stockholm, 1906.

[2] Hunziker, Otto F. The moisture content of butter and the factors which control its variations. Indiana Agricultural Experiment Station, Twenty-first Annual Report (1908), pp. 62-63. Lafayette, 1909.

Perhaps the most extensive investigation concerning the effect of the stage of lactation on the chemical and physical composition of milk was conducted at the New York Experiment Station[1] during the years 1890 to 1894, inclusive. The work was done on milk from 14 animals of Jersey, Guernsey, American Holderness, Holstein-Friesian, Devon, and Ayrshire breeds.

The object of the investigation was many-sided, including (*a*) the effect of feed on the quality and quantity of milk, (*b*) the effect of the stage of lactation on the chemical and physical composition of milk, (*c*) the relation of the several constituents of milk to the production of butter and cheese, (*d*) the suitability of the several breeds for the different dairy products, etc. Although careful records were kept of the feed given, no definite ration was fed and no attempt made to eliminate the influence of feed.

The investigation covered 4 entire lactation periods, and, briefly summarized, the figures warrant the following conclusions:

> The milk yield decreased in every case as the period of lactation advanced.
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> The fat yield followed the milk yield very closely. In general, the percentage of fat remained fairly constant up to the fifth month of the lactation period, then it steadily increased to the end.
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> The total solids, in general, after a slight decrease during the first month, showed a gradual increase as the period of lactation progressed, though the rapidity and constancy of the increase varied in different periods.
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> The casein suffered a slight decrease in the first month, then gradually increased up to about the last month, after which the increase was rapid up to the end of the lactation period. The percentage of casein was generally higher through the first period of lactation than in the 3 following periods.
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> The sugar was the most variable of the milk constituents. The general averages for all periods showed a decrease, followed by about an equal increase up to the tenth month, when there was a marked decrease to the end of the lactation period. This does not, however, hold true for each separate period; e. g., the percentage of sugar during the first lactation period tended to increase during lactation; during the second and third periods it followed the general average, while during the fourth period it tended to remain constant.
>
> The percentage of ash according to the general average remained fairly constant throughout the lactation period, despite a few variations according to the period.
>
> The physical composition depends largely upon the breed of the animal. There is, however, one general rule—the relative number of small fat globules steadily increases, with a corresponding decrease in the relative number of the large fat globules, as the period of lactation progresses. The total number of fat globules also greatly increases. The percentage of total small fat globules increased 68 per cent in the second period over the first, while the largest globules decreased 67 per cent in the second period over the first, and at the same time the intermediate-sized globules decreased to 83 per cent of what they were in the first. There was a similar change in the third period over the second. The physical changes from period to period are closely analogous to the physical changes from month to month of each lactation period.

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[1] New York Agricultural Experiment Station. Ninth, Tenth, Eleventh, Twelfth, and Thirteenth Annual Reports, Geneva, 1890 to 1894.

THE PRESENT EXPERIMENTS.

PURPOSE AND PLAN OF THE INVESTIGATION.

A review of the references made to the previous investigations regarding the effect of the stage of lactation will show that in no case were the conditions controlled to the extent of eliminating other possible causes for the variations found. It has been demonstrated that the nature of the feed has an important influence on milk, especially in regard to the composition of the fat. For this reason it is not safe to conclude that certain results obtained are to be attributed to the stage of lactation, if the ration varies from the dry feed of winter to green pasture grass of summer, as has been the case in some investigations. In planning our investigation we attempted to control these factors more completely. While the effect of the stage of lactation was the main factor under consideration, the plans were so made that the influence of breed and individuality could be studied at the same time from the data secured. Twelve animals were selected for the tests, as it was believed that this number would be sufficient to eliminate variations due to individuality of the animal and make it possible to draw correct general conclusions regarding the influence of the stage of lactation. Four breeds were selected in order that the relation of breed to variations caused by the stage of lactation could be observed and, further, that the breed characteristics could be studied at the same time.

The general plan was as follows: Twelve animals were to be used, namely, 3 each of the Holstein-Friesian, Ayrshire, Shorthorn, and Jersey breeds, the animals to be as near as possible typical specimens for the breeds—that is to say, neither inferior nor superior producers of milk, but approximately the average, or a little above, for the breed. The animals used were all purebred and registered. They were fed and cared for throughout the entire experiment under much the same conditions as would be found in a commercial dairy, except regarding the control of the feed and animals. One of the Ayrshires reacted to the tuberculin test and was put out of the experiment soon after the beginning. Table 1 gives the data in detail regarding the 11 cows that were used throughout a complete lactation period.

The milking was done by a student of the agricultural college, the precaution being taken to change milkers as little as possible. In most cases not more than one change was made during the entire milking period of the animal.

The date of beginning the sampling for analysis was that ordinarily followed in practical dairies, five days after the birth of the calf, if the cow and the milk seemed normal. The sampling was continued until the production of milk was reduced to the point where in a commercial dairy the cow would not be milked longer. The purpose in view was to give these animals such treatment as they would receive in the hands of a practical dairyman where the product was used for market milk or other purposes.

It was contemplated having the cows bred at such times as would usually be practiced in a commercial dairy in order that the next calf might be born at approximately a year from the beginning of the lactation period covered by the experiment. With some of the animals the interval between the birth of the calves was somewhat longer and in others shorter, and one of the Jersey cows, No. 118, would not breed and remained farrow throughout the period covered by the investigation. It is not unusual for this to occur with Jersey cows at the age of this cow and could not be attributed in any way to the ration given. With this exception the animals apparently remained in normal healthy condition, as shown by those indications which are usually taken to denote thrift and health, and they have since shown no ill effects from the treatment given them. The oestrum periods of the cows were as regular as usual while on the experimental ration, and the calves born later were strong and vigorous and rather larger than the average for the breeds represented.

The total yield of milk and of fat for the animals was in most cases somewhat less than the amount produced by them in previous lactation periods. However, the production during the experimental periods was more than the average of the breeds represented, and for this reason it is believed that the conditions were sufficiently normal to make the results reliable.

In addition to the 11 cows carried through an entire period of lactation, data are given of the composition throughout the lactation period of the milk of 5 Jersey cows used in another investigation. The latter differed from the 11 cows in being farrow, and they were not kept on a uniform ration.

THE FEED RATION.

The main feature of the experiment was to maintain the animals throughout the entire lactation period on an absolutely uniform ration, and at the same time keep the animals in a perfectly normal condition. A number of difficulties at once occur to the practical feeder in arranging to carry out such a plan. For instance, it is not possible to select any one ration which will be ideal for all stages of the lactation period. In the first part, when a large quantity of milk is being produced, the animal requires more concentrated feed in proportion to the roughness for the best results than at the latter part, and it is the common practice to make such a distinction in feeding. The experienced feeder supplies his animals with practically the same amount of roughness throughout the lactation period, but a larger amount of grain is fed in the early part of the period than toward the end. This practice in feeding arises from the fact that a certain amount of bulky food must be consumed by the cow at all times on account of the nature of the digestive apparatus. Any uniform ration to be fed throughout a lactation period must therefore of necessity be a compromise. This means that in the early stages of the lactation period such a ration will contain rather too much roughness in proportion to the grain, while at the latter part the reverse will be true.

In planning for this investigation it was also necessary that a ration be selected that could be secured at all times throughout a period of two or three years required to complete the work. Furthermore, such a ration must be palatable in order that the animals will relish it at all times and not become tired of it. After careful consideration the ration selected for this purpose was as follows:

Choice alfalfa hay	3 parts.
Grain (corn, 8 parts; bran, 1 part; oats, 1 part)	2 parts.

This ration supplied the protein and carbohydrates in approximately the proportions found by experience to give good results for milk production. The amount of grain was made rather large in proportion to the hay to make sure that the entire ration would be consumed at all times. The ratio between the feeding stuffs composing the ration was kept exactly the same all the time and the entire amount fed varied in proportion to the needs of the animal.

It would have been better had it been feasible to feed a certain amount of corn silage during this experiment, but the probability that at times it would not be possible to secure this food, and furthermore the wide variations in composition, prevented it from being used. The animals fared well on the ration as fed and showed no ill effects from lack of variety. Only a few times in carrying the animals through an entire lactation period were any of them "off feed," and these animals were easily brought to a normal condition by giving a dose of Epsom salt. In no case was there any serious sickness of any kind. Two of the Ayrshire cows were fed through two complete periods on this same ration with no change.

The hay, the most variable part of the ration in composition, was bought in large quantities from the same source in order that there might be but a few changes in its composition. The cows were housed in the manner common to this locality, by tying them at night in a barn for feeding and milking where the temperature was moderate; in the daytime they were turned outside and kept in a dry lot with no chance of securing feed other than that supplied. They were fed twice a day, the ration for the day being divided into two equal parts.

METHOD OF SAMPLING AND PREPARATION OF SAMPLES FOR ANALYSIS.

Special care was taken that the sample which reached the laboratory fairly represented the milk from the animal in question.

The milk was weighed after milking and mixed by pouring from one pail to another. A sample of about 1 liter was placed in a glass jar bearing the number of the cow and the number of pounds of milk for that particular milking, and delivered to the laboratory. A certain number of cubic centimeters per pound of milk were then measured out and placed in a closed receptacle to make up a composite sample to represent a week's milk from that particular cow. The number of cubic centimeters per pound was regulated by the amount of milk yielded, and varied with the individual and the amount of milk produced. As the milk flow diminished, the proportion taken for a sample increased in order that the actual volume of the composite sample might remain to insure a quantity of fat sufficient for analysis. The changes in the cubic centimeters per pound taken were always made at the beginning of a week. Formaldehyde in solution as formalin was added in amounts sufficient to preserve the sample for the 7-day period. The amount varied from 1 part formaldehyde to 5,000 parts milk to 1 part to 2,500 parts, depending upon the season of the year. When the composite sample for the week was complete it was thoroughly mixed and a subsample of about 300 cubic centimeters taken for analysis.

The remainder of the composite sample was heated to the proper temperature and the cream separated by means of a small hand-power separator. Since it was found the subsequent churning of the cream was retarded by the presence of formaldehyde, the cream was diluted with a quantity of warm water equal in volume to the skim milk removed, and again separated. The cream so obtained, usually about a liter in quantity, was churned by shaking in a glass jar of about 2 liters capacity.

The question arose at the outset of the work as to whether the butterfat so obtained represented the butterfat originally in the milk or whether the small fat globules known to have escaped in the skim and butter milk were of different chemical and physical composition from those which ultimately collected as butter. On account of the conflicting evidence on this point it seemed advisable to carry on some investigation along this line before proceeding further. The results of this work, which are published as Bulletin 111, Bureau of Animal Industry, United States Department of Agriculture, showed that there was no difference in composition between the various-sized fat globules, and therefore the fat obtained by the above procedure may be taken as truly representative of the butterfat in the milk.

The butter was immediately melted on a steam bath and allowed to remain in this condition until the curd and water had settled. Special care was taken at this point that the temperature of the fat did not rise above 50° to 55° C. and also that it remained even at this temperature no longer than was necessary.[1] It was then filtered through a paper filter kept warm by an electrical device and preserved in corked bottles which were protected from light in a refrigerator until analyzed.

METHODS OF ANALYSIS.

During the preliminary work a tendency was noticed of the subsamples of milk to churn. This was particularly true of the milk from the Jersey cows. To avoid this the procedure was followed of removing the charges for all the determinations at the same time, including the specific gravity, the remainder of the subsample being stored in the refrigerator as a reserve sample.

According to the original plan each series of determinations was to be made by the same chemist and this plan was followed with but few exceptions during the whole investigation.

The analytical methods followed were those of the Association of Official Agricultural Chemists whenever possible. Duplicate determinations were made in all cases, and in some cases triplicate or even quadruplicate Only the briefest description of the official method is given below. For a detailed description reference may be made to Bulletin 107 (revised) of the Bureau of Chemistry, United States Department of Agriculture.[2]

Specific gravity.—The specific gravity was determined by means of a Westphal balance.

Total nitrogen.—The total nitrogen was determined by the Gunning method.

Casein nitrogen.—The casein nitrogen was determined by the official method of precipitating the casein with 10 per cent acetic-acid solution and determining the nitrogen in the precipitate by the Gunning method.

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[1] According to C. A. Brown (Annual Report of the Pennsylvania State College, 1899–1900, p. 208) a temperature much above 50° C. will very soon alter the composition of butterfat. Butterfat kept at 50° C. for two days showed a loss of over one unit in iodin number.

[2] For the benefit of those who may be unfamiliar with some of the terms the following explanation may be helpful: The Reichert-Meissl number is an arbitrary measure of the volatile acids, of which butyric is the principal one in butterfat. The figures do not show the percentages of the acid, but serve as a means of comparing different fats with reference to their volatile constituents. The iodin absorption number indicates relatively the amount of iodin a fat will absorb. Since the only fatty acid found to exist in butterfat which has the property of absorbing iodin is oleic acid, the iodin absorption number shows relatively the amount of this fatty acid present, but, in common with the Reichert-Meissl number, the figures do not represent percentages. The saponification number is the number of milligrams of potassium hydroxid required to saponify 1 gram of fat. Since the amount of potassium hydroxid required depends upon the molecular weight of the fat, the saponification number serves as an indicator of the relative percentages of the fatty acids of high and low molecular weights present.

Albumin nitrogen.—The albumin nitrogen was determined by the provisional method of coagulating the albumin by heating the filtrate from the casein nitrogen determination and determining the nitrogen in the coagulum by the Gunning method.

Total solids.—The total solids were determined by the official method known as the Babcock asbestos method, employing a hollow copper cylinder and woolly asbestos.

Fat.—The fat was determined by the official Babcock asbestos method. The cylinders containing the residue from the total solids determination are extracted with ether in Soxhlet extractors, the heat being supplied by an electrical device.

Sugar.—The sugar was determined by the official optical method, using acid mercuric nitrate as the defecating agent and a Schmidt and Haensch half-shadow polariscope.

Relative size of fat globules.—The relative size of the fat globules was determined by the Babcock capillary tube method. A ⅛-inch objective and 1-inch ocular provided with a micrometer were employed. The value of each division of the micrometer scale is 0.00258 millimeter. This method is described in detail in Bulletin 111, Bureau of Animal Industry, United States Department of Agriculture.

Melting point of the butterfat.—The melting point was determined according to Wiley's method, by placing a disk of the fat in a large test tube containing boiled distilled water and boiled alcohol which had been cooled, the tube being placed in a beaker of water which was slowly heated, and noting, by means of a thermometer graduated to 0.1° C., the temperature at which the disk assumed the form of a sphere.

Refractive index of the butterfat.—The refractive index was determined with a Zeiss-Abbe refractometer which had been standardized with distilled water. The fat was kept at a constant temperature above its melting point during the determination by means of a current of warm water circulating through the instrument. The reading was reduced later by means of a factor to 25° C.

Volatile acids of the butterfat.—The method of Reichert, modified by Meissl, was employed in the estimation of the volatile acids, and the results are given as Reichert-Meissl numbers. In saponiying, use was made of the Leffman-Beam method, in which the fat is saponified in a flask over a naked flame with a mixture of a strong aqueous solution of caustic soda and pure glycerol. The soap obtained in this way is decomposed by sulphuric acid and the liberated volatile acids are distilled over with the steam and titrated with decinormal barium hydroxid solution.

Saponification value of the butterfat.—The saponification value, or Koettstorfer number, was determined by the regular official method.

The fat is saponified in a flask on a steam bath with an alcoholic potash solution, using a long glass as a reflux condenser.

Iodin absorption number of the butterfat.—The method of Hubl was employed in this case. The fat is dissolved in chloroform and subjected to the action of a mixture of an alcoholic solution of iodin and of mercuric chlorid in a dark place for 3 hours, at the end of which time the unabsorbed iodin is determined by titrating with standard sodium thiosulphate solution. The percentage of iodin absorbed by the fat is expressed in the results as the iodin number.

RESULTS OF THE EXPERIMENTS.

In presenting the results of this investigation it was decided to base the discussions mostly upon tables representing periods of 4 weeks each. All figures given for 4-week periods are the average of 4 analyses, each of which represents a sample made up, as before described, from all the milk produced in 1 week. The object in using an average representing periods of 4 weeks is that the weekly tables giving the original analyses are too unwieldy for studying the general effect of the lactation period. It is believed that the 4-week period is long enough to eliminate the daily and weekly variations which, as far as our present knowledge goes, are impossible to control and is at the same time short enough to illustrate those changes which it is the purpose of this bulletin to show. The original data giving the analyses of weekly samples from which the other tables are compiled are found in the appendix at the end of this bulletin.

In general, the data are presented in two ways, one in which the changes in the amount of each milk component during the lactation period may be studied, and the other in which the relation of each component to the others during the lactation is shown. It is the plan to eliminate as far as practicable references to the effect of breed and individuality on the chemical and physical composition of milk, this being reserved for another bulletin, which will present the same data in a way to illustrate especially this effect.

Table 1 gives the general data regarding the animals used. their age, yield of milk and fat, date of breeding, etc.

Table 2 gives the yield of milk and of fat for each cow by 4-week periods throughout the lactation period.

Table 3 gives the total yield in pounds of the several milk constituents for each animal during the lactation period.

Table 4 gives the true average composition of the milk of each cow for the entire milking period. Since both the quantity and the composition vary, a direct average from analyses made at intervals is often misleading. Most of the constituents increase greatly at the end of the milking period and at the same time the yield of milk is small. A direct average, therefore, gives a figure much higher than would be found had all the milk been gathered and sampled at one time. This error is reduced to the minimum by calculating the total weight of each constituent by periods and dividing the total produced by the total milk. Whenever an average figure is used in this report for the nitrogen, fat, sugar, or total solids the true average is meant. In considering the physical constants of the fat a direct average is used, since they vary but little and the error from such an average is too small to be of any importance.

Table 5 gives the average analysis of the milk of each cow for the complete lactation period by 4-week periods.

TABLE 1.—*Data concerning the cows used.*

No. of cow.	Breed.	Age.	Date of calving.	Date of breeding.	Period samples were taken.	Total yield of milk.	Average fat.	Total yield of fat.
		Ys. m.				*Lbs.*	*P. ct.*	*Lbs.*
4	Jersey....	6 10	Nov. 13, 1906	Dec. 30, 1906	Nov. 24, 1907, to Sept. 7, 1908	5,429	4.87	264.45
99	...do......	8 1	Jan. 1, 1907	Mar. 23, 1907	Jan. 5, 1907, to Nov. 30, 1907	6,115	4.64	284.04
118	...do......	11 4	Sept. 27, 1906	Not bred.	Oct. 6, 1906, to Oct. 26, 1907	5,733	5.36	307.45
205	Holstein.	5 3	July 17, 1907	Dec. 1, 1907	July 20, 1907, to Aug. 8, 1908	8,684	3.24	280.76
206	...do......	5 0	May 31, 1907	Sept. 28, 1907	June 1, 1907, to Apr. 4, 1908	8,994	2.93	263.66
209	...do......	3 8	July 20, 1907	Nov. 18, 1907	July 20, 1907, to July 4, 1908	8,814	3.02	273.34
300	Ayrshire.	3 8	Dec. 28, 1907	Feb. 23, 1908	Dec. 29, 1907, to Oct. 3, 1908	6,275	3.51	220.34
301	...do.....	4 8	Sept. 27, 1907	Mar. 16, 1908	Sept. 29, 1907, to Sept. 19, 1908	6,382	3.85	245.64
400	Shorthorn	4 4	Sept. 30, 1907	Jan. 25, 1908	Oct. 5, 1907, to Aug. 1, 1908	5,172	3.89	201.37
402	...do.....	4 11	Oct. 13, 1907	Dec. 21, 1907	Oct. 19, 1907, to July 18, 1908	4,449	4.13	183.57
403	...do......	6 0	Feb. 11, 1908	July 7, 1908	Feb. 15, 1908, to Dec. 19, 1908	6,539	3.35	220.52

TABLE 2.—*Milk and butterfat produced by each cow, and average for each breed, by 4-week periods.*

Cow No.	First period.		Second period.		Third period.		Fourth period.		Fifth period.		Sixth period.		Seventh period.	
	Milk.	Fat.	Milk.	Fat.	Milk.	Fat.	Milk.	Fat.	Milk.	Fat.	Milk.	Fat.	Milk.	Fat.
	Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
4............	770.8	39.80	738.4	34.18	557.7	28.07	556.2	26.96	578.8	27.85	471.9	23.56	476.0	22.50
99...........	708.9	37.02	690.1	33.02	701.0	31.05	628.7	27.62	518.9	22.41	550.0	23.21	490.2	21.37
118..........	428.4	......	376.2	......	423.9	23.41	475.7	24.34	418.9	23.09	440.2	25.15	449.7	25.57
Average for Jerseys....	636.0	38.41	601.6	33.60	560.9	27.51	553.5	26.31	505.5	24.45	487.4	23.97	472.0	23.15
205..........	788.0	25.05	860.8	27.06	827.5	24.94	750.4	24.28	742.9	24.45	690.7	21.12	666.1	21.70
206..........	1,360.6	41.61	1,267.1	36.62	970.5	25.00	872.4	24.79	858.1	24.77	773.3	23.68	718.5	20.72
209..........	1,026.1	30.81	1,086.5	28.19	940.9	25.72	818.5	26.64	711.7	22.22	724.7	20.35	700.3	20.60
Average for Holsteins.	1,058.2	32.49	1,071.5	30.62	913.0	25.22	813.8	25.24	770.9	23.81	729.6	21.72	695.0	21.01
300..........	837.9	33.53	871.8	31.37	869.0	29.35	778.5	26.18	741.7	24.60	738.1	24.04	576.3	19.08
301..........	612.3	23.42	582.6	21.80	539.4	20.53	570.5	21.72	533.1	21.77	595.7	22.49	572.4	22.60
Average for Ayrshires.	725.1	28.48	727.2	26.59	704.2	24.94	674.5	23.95	637.4	23.18	666.9	23.27	574.4	20.84
400..........	680.9	27.99	662.6	27.11	456.6	18.25	501.7	18.33	565.9	20.92	538.8	19.86	501.2	19.23
402..........	647.1	29.44	576.3	24.05	532.0	21.13	518.7	19.70	512.3	19.68	486.0	19.00	437.6	17.40
403..........	909.7	32.43	859.8	29.05	829.9	26.33	768.1	24.25	681.4	21.43	625.9	19.56	569.9	18.42
Average for Shorthorns	745.9	29.95	699.6	26.74	606.2	21.90	596.2	20.76	586.5	20.68	550.2	19.47	502.9	18.35

TABLE 2.—*Milk and butterfat produced by each cow, and average for each breed, by 4-week periods*—Continued.

Cow No.	Eighth period.		Ninth period.		Tenth period.		Eleventh period.		Twelfth period.		Thirteenth period.		Fourteenth period.	
	Milk.	Fat.	Milk.	Fat.	Milk.	Fat.	Milk.	Fat.	Milk.	Fat.	Milk.	Fat.	Milk.	Fat.
	Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
4	446.6	20.13	378.7	17.92	454.4	23.48	......	......	......	......	......	......	......	......
99	494.5	20.70	484.1	22.38	446.0	22.14	280.7	15.71	122.1	7.41	......	......	......	......
118	413.3	23.97	456.0	23.58	469.3	21.04	446.7	21.56	417.8	22.01	366.3	20.02	150.9	9.74
Average for Jerseys	451.5	21.60	439.6	21.29	456.6	22.22	363.7	18.64	270.0	14.71	366.3	20.02	150.9	9.74
205	640.4	20.78	648.1	20.38	598.7	19.78	574.4	18.97	445.2	15.55	311.6	11.50	139.7	5.20
206	701.4	20.99	682.4	20.42	561.2	17.31	228.9	7.75	......	......	......	......	......	......
209	717.0	21.59	711.5	21.39	520.3	18.28	477.7	16.35	273.4	10.65	......	......	......	......
Average for Holsteins	686.3	21.12	680.7	20.73	560.1	18.46	427.0	14.36	359.3	13.10	311.6	11.50	139.7	5.20
300	435.8	15.42	303.1	11.20	123.6	5.57	......	......	......	......	......	......	......	......
301	531.1	20.90	566.0	20.77	587.7	21.03	332.9	14.21	235.0	9.30	123.7	5.10	......	......
Average for Ayrshires	483.5	18.16	434.6	15.99	355.6	13.30	332.9	14.21	235.0	9.30	123.7	5.10	......	......
400	517.9	19.32	424.6	17.05	217.7	9.01	103.3	4.30	......	......	......	......	......	......
402	392.6	15.31	246.9	13.45	99.5	4.41	......	......	......	......	......	......	......	......
403	477.5	16.87	368.8	14.17	273.4	10.94	......	......	......	......	......	......	......	......
Average for Shorthorns	462.7	17.17	346.8	14.89	196.9	8.12	103.3	4.30	......	......	......	......	......	......

TABLE 3.—*Total yield of milk and milk constituents by each cow.*

Cow No.	Total milk.	Total solids.	Fat.	Nitrogen.							Sugar.	Ash.
				Total nitrogen.	Protein (N× 6.38).	Casein nitrogen.	Casein (N× 6.38).	Albumin nitrogen.	Albumin (N× 6.38).	Residual nitrogen.		
	Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
4	5,430	764.6	264.5	31.5	200.7	25.2	160.7	3.6	19.5	2.7	263.7	38.0
99	6,115	821.5	284.0	31.4	200.4	25.4	162.4	2.4	15.3	3.6	302.8	45.3
118	5,733	850.5	307.5	35.7	227.6	28.2	179.8	3.7	23.6	3.8	275.3	42.4
205	8,685	1,042.7	280.8	40.9	260.8	33.5	213.9	2.9	18.5	4.5	438.7	56.4
206	8,994	964.1	263.7	38.1	243.0	29.8	190.4	3.1	19.6	5.2	383.3	63.0
209	8,815	997.1	273.3	44.3	282.8	34.8	221.9	3.9	24.8	5.6	375.0	61.7
300	6,276	757.9	220.3	30.6	195.1	25.9	164.9	1.8	11.8	2.9	304.6	40.2
301	6,382	811.5	245.6	33.3	212.4	27.8	177.2	2.4	15.4	3.1	316.5	38.9
400	5,171	676.2	201.4	27.6	175.8	22.4	143.0	2.4	15.4	2.8	260.6	37.8
402	4,449	599.0	183.6	24.3	155.3	19.9	126.9	2.1	13.2	2.3	218.5	32.5
403	6,540	796.0	220.5	33.6	214.6	26.8	170.7	3.2	20.3	3.6	326.0	45.1

TABLE 4.—*True average composition of the milk of each cow.*

Cow No.	Average total solids.	Average solids not fat.	Average total nitrogen.	Average protein.	Average casein nitrogen.	Average casein.	Average albumin nitrogen.	Average albumin.	Average residual nitrogen.	Average fat.	Average sugar.	Average ash.
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
4.....	14.08	9.21	0.58	3.70	0.46	2.95	0.056	0.359	0.064	4.87	4.85	0.70
99....	13.43	8.79	.51	3.27	.42	2.65	.039	.249	.051	4.64	4.95	.74
118...	14.83	9.47	.62	3.97	.49	3.14	.064	.411	.066	5.36	4.80	.74
205...	12.00	8.80	.47	3.00	.39	2.46	.033	.213	.047	3.23	5.05	.65
206...	10.70	7.80	.42	2.70	.33	2.12	.034	.218	.056	2.93	4.26	.70
209...	11.30	8.20	.50	3.21	.39	2.52	.044	.281	.066	3.10	4.25	.70
300...	12.10	8.60	.49	3.11	.41	2.63	.029	.188	.051	3.51	4.85	.64
301...	12.70	8.90	.52	3.33	.44	2.78	.038	.241	.042	3.85	4.96	.61
400...	13.10	9.20	.53	3.40	.43	2.77	.047	.297	.053	3.89	5.04	.73
402...	13.50	9.30	.55	3.49	.45	2.85	.046	.296	.054	4.13	4.91	.73
403...	12.20	8.80	.51	3.28	.41	2.61	.049	.310	.042	3.37	4.98	.69

TABLE 5.—*Average analysis of the milk of each cow, by 4-week periods.*

COW NO. 4.

Four weeks ending—	Specific gravity of milk.	Water.	Total solids.	Solids not fat.	Total nitrogen.	Casein nitrogen.	Albumin nitrogen.	Fat.	Sugar.
1906.		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Dec. 22.............	1.0345	85.87	14.13	9.51	0.52	0.44	0.059	5.17	4.89
1907.									
Jan. 19.............	1.0330	....	....	....	.53	.38	.056	4.63	4.99
Feb. 16.............	1.0338	....	....	....	.57	.48	.057	5.07	4.87
Mar. 16.............	1.0340	85.56	14.44	9.51	.61	.49	.067	4.85	5.28
Apr. 13.............	1.0338	85.72	14.28	9.10	.60	.48	.045	4.81	5.12
May 11.............	1.0337	85.85	14.15	8.90	.59	.48	.031	5.00	5.00
June 8.............	1.0326	86.13	13.87	9.14	.59	.47	.064	4.73	4.39
July 6.............	1.0327	86.23	13.77	9.41	.57	.46	.061	4.51	4.45
Aug. 3.............	1.0334	86.38	13.63	9.02	.62	.50	.062	4.73	4.67
Sept. 7[1]............	1.0338	85.43	14.57	9.39	.66	.52	.063	5.18	4.60
COW NO. 99.									
1907.									
Feb. 2.............	1.0329	....	....	....	0.51	0.42	0.038	5.22	4.94
Mar. 2.............	1.0327	86.91	13.09	8.72	.51	.41	.054	4.79	5.15
Mar. 30.............	1.0333	86.71	13.30	8.86	.51	.40	.037	4.43	5.17
Apr. 27.............	1.0326	86.85	13.15	8.75	.49	.40	.025	4.40	5.05
May 25.............	1.0322	87.09	12.92	8.59	.49	.40	.029	4.33	5.04
June 22.............	1.0314	87.24	12.76	8.54	.49	.40	.043	4.22	4.50
July 20.............	1.0310	86.96	13.04	8.77	.48	.39	.036	4.36	4.52
Aug. 17.............	1.0322	87.19	12.81	8.63	.50	.40	.041	4.18	5.14
Sept. 14.............	1.0328	86.65	13.35	8.72	.52	.42	.035	4.63	4.62
Oct. 12.............	1.0337	85.74	14.27	9.29	.56	.46	.043	4.98	5.03
Nov. 9.............	1.0343	84.85	15.15	9.54	.62	.51	.042	5.62	5.02
Nov. 30.............	1.0343	83.92	16.08	10.01	.66	.53	.071	6.07	5.61
COW NO. 118.									
1906.									
Nov. 3.............	....	....	....	....	....	....	....	....	....
Dec. 1.............	1.0302	85.92	14.08	8.77	0.51	0.32	0.081	5.31	4.47
Dec. 29.............	1.0302	85.45	14.55	8.97	.56	.48	.051	5.55	4.70
1907.									
Jan. 26.............	1.0324	....	....	....	.54	.42	.057	5.11	4.56
Feb. 23.............	1.0340	....	....	....	.65	.54	.074	5.51	4.83
Mar. 23.............	1.0345	84.70	15.30	9.59	.65	.52	.071	5.71	5.21
Apr. 20.............	1.0344	84.84	15.16	9.44	.67	.54	.049	5.69	5.20
May 18.............	1.0346	84.39	15.61	9.81	.64	.54	.057	5.80	5.40
June 15.............	1.0341	85.21	14.79	9.63	.64	.51	.062	5.17	4.57
July 13.............	1.0336	85.55	14.45	9.67	.64	.50	.069	4.47	4.73
Aug. 10.............	1.0349	85.58	14.42	9.65	.65	.51	.062	4.83	4.90
Sept. 7.............	1.0356	84.92	15.08	9.80	.70	.55	.065	5.28	4.72
Oct. 5.............	1.0361	83.90	16.10	10.67	.75	.61	.061	5.48	4.46
Oct. 26[2]............	1.0355	82.84	17.16	10.70	.77	.58	.062	6.47	5.22

[1] Last period, five weeks.

[2] Last period, three weeks.

TABLE 5.—*Average analysis of the milk of each cow, by 4-week periods*—Continued.

COW NO. 205.

Four weeks ending—	Specific gravity of milk.	Water.	Total solids.	Solids not fat.	Total nitrogen.	Casein nitrogen.	Albumin nitrogen.	Fat.	Sugar.
1907.		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Aug. 17	1.0338	88.26	11.74	8.50	0.49	0.40	0.041	3.24	4.69
Sept 14	1.0327	88.43	11.58	8.43	.43	.35	.032	3.14	4.98
Oct. 12	1.0328	88.30	11.70	8.68	.44	.34	.031	3.02	4.84
Nov. 9	1.0326	88.05	11.95	8.70	.44	.36	.032	3.25	5.18
Dec. 7	1.0325	87.89	12.11	8.82	.45	.37	.034	3.29	5.42
1908.									
Jan. 4	1.0330	88.23	11.77	8.96	.45	.38	.032	3.06	5.37
Feb. 1	1.0327	88.02	11.98	8.72	.45	.37	.037	3.26	5.20
Feb. 29	1.0333	87.84	12.16	8.92	.44	.37	.036	3.25	4.76
Mar. 28	1.0329	88.06	11.95	8.80	.48	.38	.027	3.15	5.10
Apr. 25	1.0322	87.89	12.12	8.81	.48	.39	.032	3.31	5.12
May 23	1.0329	87.81	12.20	8.89	.51	.43	.035	3.31	5.13
June 20	1.0335	87.50	12.50	9.01	.55	.45	.038	3.49	5.02
July 18	1.0331	86.97	13.04	9.36	.59	.51	.025	3.68	4.89
Aug. 8	1.0333	86.58	13.42	9.74	.65	.57	.027	3.68	4.81

COW NO. 206.

Four weeks ending—	Specific gravity of milk.	Water.	Total solids.	Solids not fat.	Total nitrogen.	Casein nitrogen.	Albumin nitrogen.	Fat.	Sugar.
1907.									
June 29	1.0294	89.05	10.95	7.88	0.44	0.34	0.042	3.07	4.07
July 27	1.0293	89.90	10.10	7.47	.38	.30	.028	2.88	4.49
Aug. 24	1.0294	89.82	10.18	7.60	.37	.29	.030	2.58	4.44
Sept. 21	1.0281	89.74	10.27	7.42	.39	.30	.022	2.84	4.12
Oct. 19	1.0295	89.46	10.54	7.66	.42	.32	.028	2.89	4.26
Nov. 16	1.0289	89.27	10.73	7.67	.42	.33	.034	3.06	4.04
Dec. 14	1.0288	89.25	10.75	7.87	.41	.31	.040	2.88	4.74
1908.									
Jan. 11	1.0291	89.20	10.80	7.80	.43	.33	.036	3.00	4.25
Feb. 8	1.0302	88.99	11.01	8.02	.44	.36	.036	3.00	4.09
Mar. 7	1.0316	88.10	11.90	8.81	.51	.42	.039	3.09	3.94
Apr. 4	1.0345	86.70	13.30	9.73	.71	.58	.065	3.40	4.50

COW NO. 209.

Four weeks ending—	Specific gravity of milk.	Water.	Total solids.	Solids not fat.	Total nitrogen.	Casein nitrogen.	Albumin nitrogen.	Fat.	Sugar.
1907.									
Aug. 17	1.0318	88.76	11.24	8.12	0.50	0.39	0.051	3.12	4.40
Sept. 14	1.0305	89.77	10.23	7.63	.45	.34	.032	2.60	4.00
Oct. 12	1.0300	89.37	10.63	7.90	.45	.34	.037	2.74	4.17
Nov. 9	1.0299	88.93	11.07	8.05	.47	.36	.038	3.24	3.95
Dec. 7	1.0297	88.85	11.15	8.02	.45	.35	.034	3.14	4.42
1908.									
Jan. 4	1.0303	89.05	10.96	8.14	.46	.36	.042	2.81	4.36
Feb. 1	1.0305	88.80	11.20	8.27	.50	.39	.044	2.94	4.16
Feb. 29	1.0306	88.78	11.23	8.46	.49	.40	.047	3.01	3.94
Mar. 28	1.0313	88.42	11.58	8.57	.52	.41	.038	3.01	4.43
Apr. 25	1.0325	87.42	12.58	9.06	.60	.49	.057	3.52	4.62
May 23	1.0344	87.02	12.99	9.53	.65	.53	.063	3.46	4.79
June 22	1.0348	86.49	13.51	9.61	.73	.59	.084	3.90	4.15
July 4[1]	1.0322	85.48	14.52	9.25	.71	.58	.067	5.28	4.30

COW NO. 300.

Four weeks ending—	Specific gravity of milk.	Water.	Total solids.	Solids not fat.	Total nitrogen.	Casein nitrogen.	Albumin nitrogen.	Fat.	Sugar.
1908.									
Jan. 25	1.0329	86.93	13.07	9.06	0.53	0.44	0.039	4.01	5.14
Feb. 22	1.0325	87.73	12.27	8.66	.47	.40	.031	3.61	4.81
Mar. 21	1.0326	87.86	12.14	8.76	.48	.40	.027	3.38	4.64
Apr. 18	1.0308	88.19	11.81	8.45	.47	.38	.030	3.36	4.87
May 16	1.0313	88.35	11.66	8.34	.46	.39	.031	3.32	4.96
June 13	1.0302	88.66	11.35	8.09	.47	.39	.029	3.26	4.57
July 11	1.0300	88.62	11.38	8.07	.46	.39	.029	3.30	4.82
Aug. 8	1.0309	87.86	12.15	8.62	.49	.44	.019	3.53	5.08
Sept. 5	1.0320	87.44	12.56	8.82	.57	.52	.017	3.74	5.13
Oct. 3	1.0319	86.15	13.85	9.33	.67	.59	.032	4.52	4.39

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[1] Last period, two weeks.

Table 5.—*Average analysis of the milk of each cow, by 4-week periods*—Continued.

COW NO. 301.

Four weeks ending—	Specific gravity of milk.	Water.	Total solids.	Solids not fat.	Total. nitrogen.	Casein nitrogen.	Albumin nitrogen.	Fat.	Sugar.
1907.		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Oct. 26	1.0343	86.80	13.20	9.31	0.56	0.47	0.043	3.87	5.17
Nov. 23	1.0327	87.51	12.50	8.76	.50	.40	.032	3.74	4.72
Dec. 21	1.0326	87.43	12.57	8.76	.48	.39	.042	3.81	5.62
1908.									
Jan. 18	1.0324	87.37	12.64	8.83	.51	.43	.035	3.81	5.16
Feb. 15	1.0328	86.91	13.09	9.01	.51	.43	.042	4.08	4.77
Mar. 14	1.0331	87.15	12.86	9.08	.53	.43	.046	3.78	4.43
Apr. 11	1.0324	87.37	12.63	8.70	.51	.42	.043	3.95	5.38
May 9	1.0320	87.36	12.64	8.70	.50	.42	.036	3.94	5.13
June 6	1.0321	87.51	12.49	8.82	.53	.45	.033	3.67	4.85
July 4	1.0310	88.22	11.78	8.21	.53	.43	.036	3.58	4.88
Aug. 1	1.0289	86.46	13.55	8.63	.53	.46	.033	4.92	4.89
Aug. 29	1.0318	86.96	13.04	9.08	.57	.52	.024	3.96	5.04
Sept. 19	1.0343	86.43	13.27	9.09	.65	.57	.032	4.18	5.13

COW NO. 400.

1907.									
Nov. 2	1.0355	86.29	13.71	9.60	0.54	0.45	0.055	4.12	5.40
Nov. 30	1.0332	86.71	13.29	9.20	.51	.41	.053	4.09	5.06
Dec. 28	1.0333	86.95	13.05	9.06	.46	.38	.033	3.99	5.44
1908.									
Jan. 25	1.0330	87.52	12.48	8.84	.48	.38	.043	3.65	5.13
Feb. 22	1.0343	86.94	13.06	9.37	.53	.44	.045	3.70	4.87
Mar. 21	1.0340	86.95	13.05	9.36	.54	.44	.043	3.69	4.95
Apr. 18	1.0341	87.04	12.96	9.11	.56	.45	.057	3.85	5.05
May 16	1.0344	86.92	13.08	9.35	.56	.46	.046	3.73	5.19
June 13	1.0329	86.97	13.03	8.98	.58	.45	.046	4.05	4.65
July 11	1.0304	87.57	12.43	8.28	.60	.48	.038	4.16	4.22
Aug. 1	1.0298	87.16	12.84	8.67	.59	.53	.027	4.17	4.25

COW NO. 402.

1907.									
Nov. 16	1.0341	86.27	13.74	9.19	0.53	0.44	0.051	4.55	4.77
Dec. 14	1.0336	86.71	13.29	9.12	.52	.43	.049	4.17	5.32
1908.									
Jan. 11	1.0335	86.93	13.07	9.10	.51	.42	.047	3.97	5.09
Feb. 8	1.0340	86.94	13.07	9.27	.54	.44	.046	3.80	4.72
Mar. 7	1.0337	86.87	13.16	9.32	.55	.45	.045	3.84	4.55
Apr. 4	1.0339	87.03	12.97	9.06	.55	.44	.045	3.92	5.09
May 2	1.0333	86.98	13.02	9.04	.55	.45	.042	3.98	5.29
May 30	1.0335	87.07	12.93	9.04	.57	.45	.042	3.90	4.73
June 27	1.0332	86.20	13.81	9.14	.63	.53	.055	4.67	4.61
July 18	1.0326	86.06	13.94	9.52	.70	.56	.029	4.42	4.31

COW NO. 403.

1908.									
Mar. 14	1.0348	87.15	12.85	9.27	0.52	0.42	0.053	3.58	5.21
Apr. 11	1.0328	87.85	12.16	8.78	.49	.38	.051	3.38	5.22
May 9	1.0327	88.25	11.75	8.57	.47	.36	.043	3.18	5.39
June 6	1.0317	88.44	11.56	8.40	.47	.37	.044	3.16	5.00
July 4	1.0315	88.44	11.56	8.42	.49	.37	.045	3.14	4.58
Aug. 1	1.0313	88.36	11.65	8.52	.51	.43	.033	3.13	5.16
Aug. 29	1.0321	87.23	12.77	9.54	.53	.46	.030	3.23	4.98
Sept. 26	1.0333	87.48	12.52	8.97	.57	.47	.045	3.55	5.11
Oct. 24	1.0334	87.62	12.38	8.54	.58	.46	.067	3.85	4.08
Nov. 21	1.0321	87.10	12.90	8.90	.60	.45	.093	4.00	4.17
Dec. 19	1.0327	86.81	13.19	9.15	.64	.48	.092	4.05	4.47

TABLE 5.—*Average analysis of the milk of each cow, by 4-week periods*—Continued.

COW NO. 4.

Four weeks ending—	Ash.[1]	Relative size of globules.	Reichert-Meissl number.	Iodin number.	Saponification number.	Refractive index.	Melting point.
1906.	*Per cent.*						°*C.*
Dec. 22		363	29.22	31.08	231.1	1.4601	32.36
1907.							
Jan. 19		423	28.72	28.04	233.1	1.4595	32.63
Feb. 16		370	28.52	29.61	232.9		33.39
Mar. 16		229	28.50	29.94	229.1	1.4594	33.25
Apr. 13		267	28.96	28.84	230.7	1.4593	33.30
May 11		235	29.20	28.03	229.0	1.4592	33.44
June 8		299	26.87	31.46	227.8	1.4589	32.94
July 6		318	28.63	29.75	229.4	1.4594	33.24
Aug. 3		228	25.24	32.27	234.4		33.03
Sept. 7[2]		167	25.95	32.15	235.9	1.4584	32.97

COW NO. 99.

Four weeks ending—	Ash.[1]	Relative size of globules.	Reichert-Meissl number.	Iodin number.	Saponification number.	Refractive index.	Melting point.
1907.							
Feb. 2		556	30.16	32.68	230.6	1.4601	24.94
Mar. 2		339	28.88	29.46	232.1	1.4597	33.24
Mar. 30		325	32.09	28.96	229.5	1.4592	33.36
Apr. 27		274	30.95	26.75	232.3	1.4589	34.53
May 25		264	27.67	29.99	227.7		33.78
June 22		349	31.21	27.29	231.7	1.4590	34.06
July 20	0.65	370	27.03	27.93	227.3		34.07
Aug. 17	.64	367	27.34	27.37	239.8	1.4580	34.33
Sept. 14	.65	270	27.03	28.71	234.3		34.64
Oct. 12	.76	209	25.83	28.80	231.4	1.4558	33.81
Nov. 9	.81	263	24.73	27.61	229.4	1.4564	34.88
Nov. 30	.91	315	18.43	29.55	219.6	1.4567	34.35

COW NO. 118.

Four weeks ending—	Ash.[1]	Relative size of globules.	Reichert-Meissl number.	Iodin number.	Saponification number.	Refractive index.	Melting point.
1906.							
Nov. 3			29.54	39.31	228.5		26.62
Dec. 1			23.28	36.33	224.7		32.66
Dec. 29		417	24.14	32.54	229.6	1.4604	33.31
1907.							
Jan. 26		879	23.69	28.69	229.0	1.4602	33.31
Feb. 23		358	23.90	31.55	230.2	1.4600	33.80
Mar. 23		373	24.64	30.43	226.6	1.4596	33.40
Apr. 20		301	26.66	28.67	229.4	1.4596	33.92
May 18		334	23.12	32.49	224.8	1.4602	33.66
June 15		335	25.04	33.67	225.1	1.4601	33.39
July 13	0.64	259	22.85	31.43	227.6		33.59
Aug. 10	.69	342	22.79	31.14	237.0	1.4578	33.81
Sept. 7	.76	229	20.22	32.47	223.9	1.4592	33.68
Oct. 5	.85	438	14.23	38.48	219.5	1.4570	33.46
Oct. 26[1]		461	14.21	35.82	219.1	1.4579	33.50

COW NO. 205.

Four weeks ending—	Ash.[1]	Relative size of globules.	Reichert-Meissl number.	Iodin number.	Saponification number.	Refractive index.	Melting point.
1907.							
Aug. 17	0.64	242	26.66	37.12	242.2	1.4598	33.41
Sept. 14	.61	147	26.01	34.54	229.3		32.67
Oct. 12	.64	148	26.33	33.23	229.0	1.4559	33.39
Nov. 9	.69	147	27.38	31.85	232.9		33.76
Dec. 7	.69	127	27.82	31.77	230.8	1.4568	33.02
1908.							
Jan. 4	.66	82	26.92	32.64	228.7	1.4571	32.93
Feb. 1	.59	107	28.05	32.62	228.1	1.4564	32.88
Feb. 29	.63	96	27.53	33.45	227.0	1.4566	32.98
Mar. 28	.62	98	27.86	34.07	225.0		33.26
Apr. 25	.62	90	26.06	35.55	223.9		33.09
May 23	.63	81	25.63	35.40	226.3		33.01
June 20	.65	117	20.39	37.53	220.8		32.54
July 18		102	12.77	42.57	210.1		41.80
Aug. 8	.70	179	10.27	42.24	205.9		48.34

[1] Ash not determined for cow No. 4.

[2] Last period, 5 weeks.

TABLE 5.—*Average analysis of the milk of each cow, by 4-week periods*—Continued.

COW NO. 206.

Four weeks ending—	Ash.	Relative size of globules.	Reichert-Meissl number.	Iodin number.	Saponification number.	Refractive index.	Melting point.
1907.	*Per cent.*						°*C.*
June 29	....	253	30.15	31.00	230.7	....	32.95
July 27	0.62	269	29.48	30.57	228.3	....	33.52
Aug. 24	.64	124	28.15	35.53	242.4	1.4584	31.94
Sept. 21	.71	157	24.58	31.70	233.7	1.4559	32.06
Oct. 19	.66	134	27.19	31.79	232.4	1.4565	32.47
Nov. 16	....	155	24.51	31.67	231.2	....	32.47
Dec. 14	.67	132	24.28	33.14	229.7	1.4569	32.64
1908.							
Jan. 11	.67	110	23.39	34.25	225.6	1.4576	33.13
Feb. 8	.67	96	23.53	33.91	224.4	1.4573	32.81
Mar. 7	.83	74	20.76	35.27	219.9	1.4575	32.92
Apr. 4	.86	79	17.62	36.53	216.4	....	38.80

COW No. 209.

1907.							
Aug. 17	0.72	321	25.65	39.46	237.2	1.4598	32.58
Sept. 14	.69	139	26.84	33.32	230.6	....	32.16
Oct. 12	.66	136	25.10	32.89	231.6	1.4565	32.06
Nov. 9	.71	138	27.05	33.10	230.8	....	31.84
Dec. 7	.75	104	24.82	33.53	228.3	1.4576	33.04
1908.							
Jan. 4	.64	89	24.68	34.91	229.0	1.4578	31.69
Feb. 1	.67	98	22.79	36.62	224.0	1.4574	32.30
Feb. 29	.70	99	23.47	35.59	222.4	1.4570	32.78
Mar. 28	.71	105	24.23	37.01	222.0	....	32.85
Apr. 25	.74	79	20.17	39.08	219.2	....	33.82
May 23	.66	63	21.32	35.35	222.0	....	33.15
June 22	.68	76	20.70	36.69	220.3	....	35.45
July 4[1]	.76	118	21.14	39.03	215.3	....	37.39

COW No. 300.

1908.							
Jan. 25	0.66	235	27.66	32.58	232.6	1.4569	34.80
Feb. 22	.67	163	28.96	28.70	230.7	1.4554	33.39
Mar. 21	.67	148	27.76	27.69	232.3	....	33.45
Apr. 18	.68	135	25.76	31.91	224.8	....	33.54
May 16	.66	115	26.83	27.50	229.2	....	33.74
June 13	.62	133	25.76	29.61	230.1	....	33.87
July 11	.68	93	24.57	35.30	224.5	....	33.83
Aug. 8	.61	80	23.87	37.32	222.0	....	33.30
Sept. 5	.57	75	23.09	35.23	223.9	....	33.30
Oct. 3	....	129	17.96	37.74	217.2	....	34.04

COW NO. 301.

1907.							
Oct. 26	0.64	232	30.59	28.58	236.9	1.4564	32.07
Nov. 23	.66	189	27.09	29.91	234.1	1.4567	33.21
Dec. 21	.67	142	26.58	30.56	232.0	1.4569	32.61
1908.							
Jan. 18	.59	155	25.13	29.85	230.4	1.4563	32.80
Feb. 15	.60	165	24.88	30.93	227.5	1.4563	33.85
Mar. 14	.64	178	26.79	30.31	229.7	....	32.98
Apr. 11	.62	163	25.59	31.04	219.6	....	33.98
May 9	.55	151	26.40	30.54	228.3	....	33.55
June 6	....	146	24.42	32.64	228.4	....	33.33
July 4	.60	114	24.36	35.11	224.3	....	33.10
Aug. 1	.51	146	18.09	44.11	216.2	....	34.35
Aug. 29	.55	93	21.72	39.62	218.7	....	33.23
Sept. 19	.70	110	20.67	36.80	221.3	....	33.28

TABLE 5.—*Average analysis of the milk of each cow, by 4-week periods*—Continued.

COW NO. 400.

Four weeks ending—	Ash.	Relative size of globules.	Reichert-Meissl number.	Iodin number.	Saponification number.	Refractive index.	Melting point.
1907.	*Per cent.*						°*C.*
Nov. 2	0.70	442	30.77	30.13	232.3	....	33.91
Nov. 30	.72	593	29.31	32.12	231.7	1.4570	32.99
Dec. 28	.69	317	25.95	39.06	224.2	1.4581	31.61
1908.							
Jan. 25	.67	245	25.99	31.36	230.0	1.4563	33.15
Feb. 22	.67	250	28.58	31.66	229.4	1.4557	33.01
Mar. 21	.75	277	26.54	33.31	227.2	....	33.88
Apr. 18	.72	231	24.70	35.71	223.9	....	33.63
May 16	.70	197	25.99	33.25	226.5	....	34.13
June 13	....	214	24.46	34.28	224.9	....	34.21
July 11	.79	179	22.57	36.91	220.5	....	36.40
Aug. 1	.85	194	22.25	38.49	216.8	....	36.49
COW NO. 402.							
1907.							
Nov. 16	0.71	566	30.72	30.76	234.3	....	32.69
Dec. 14	.72	561	27.14	29.21	233.9	1.4566	32.79
1908.							
Jan. 11	.70	394	26.69	31.15	229.8	1.4560	33.20
Feb. 8	.71	274	25.60	30.42	223.0	1.4560	33.09
Mar. 7	.72	280	26.07	32.08	228.3	....	32.95
Apr. 4	.72	232	24.12	35.16	224.3	....	33.99
May 2	.74	271	23.75	35.13	223.7	....	33.76
May 30	.72	214	22.93	35.47	222.7	....	33.79
June 27	.69	213	18.39	41.01	215.8	....	34.65
July 18	.86	193	16.61	42.19	211.5	....	36.31
COW NO. 403.							
1908.							
Mar. 14	....	357	29.36	33.33	234.3	....	32.70
Apr. 11	0.67	303	26.67	35.18	225.4	....	33.32
May 9	.71	213	26.31	33.19	228.1	....	32.70
June 6	.66	183	26.30	33.75	229.9	....	32.60
July 4	.61	134	25.69	35.28	226.4	....	33.15
Aug. 1	.57	141	26.02	35.57	230.1	....	32.98
Aug. 29	.69	146	26.38	34.96	224.6	....	32.54
Sept. 26	.69	147	24.53	36.34	225.1	....	32.65
Oct. 24	.69	203	23.27	37.32	223.8	....	33.14
Nov. 21	.76	175	24.25	35.24	226.4	....	33.28
Dec. 19	.87	128	25.51	35.04	226.6	....	32.83

TOTAL NITROGEN AND PROTEIN.

Table 6 gives the average per cent of total nitrogen in the milk of each of the 11 cows by 4-week periods. The figures for the individuals are also grouped by breeds in order that an average may be given representing each breed, and a grand average including all. The averages are also expressed in per cent of protein (N×6.38). The changes in the total protein for each cow by 4-week periods is represented in figures 1 to 11, and average for the 11 animals in figure 12.

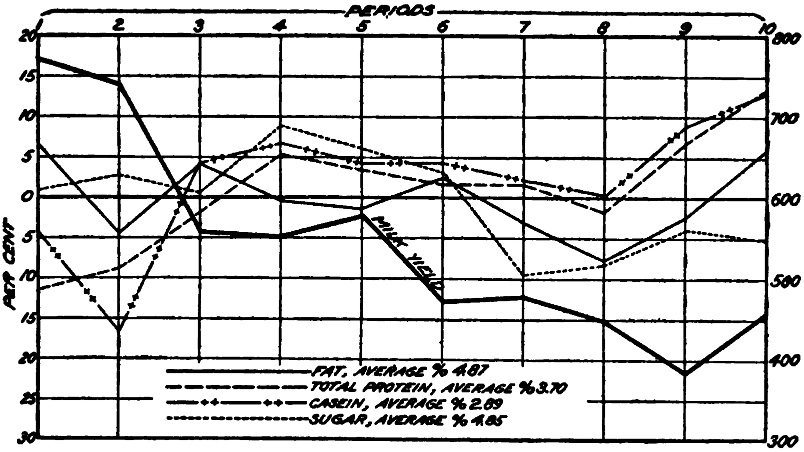

FIG. 1.—Diagram showing variation in yield and composition of milk of cow No. 4 at end of each 4-week period.

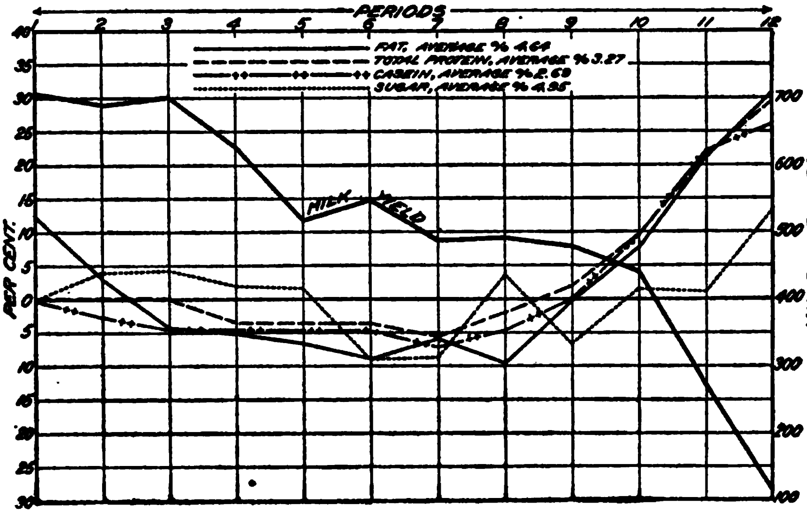

FIG. 2.—Diagram showing variation in yield and composition of milk of cow No. 99 at end of each 4-week period.

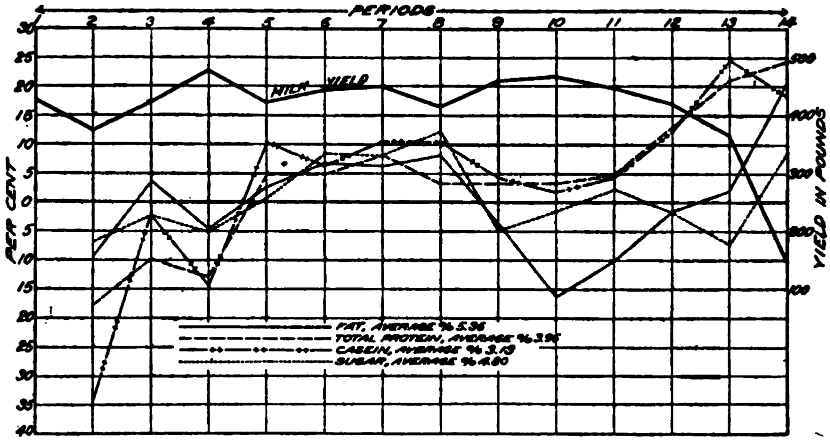

FIG. 3.—Diagram showing variation in yield and composition of milk of cow No. 118 at end of each 4-week period.

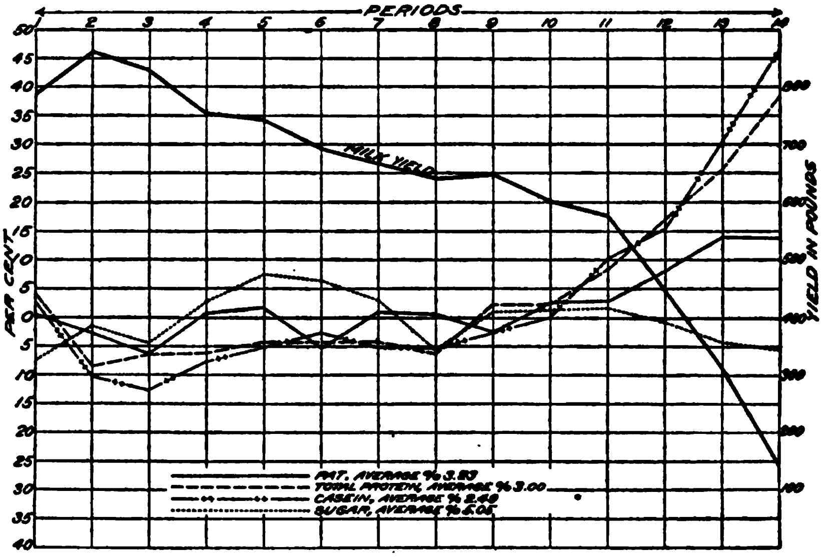

FIG. 4.—Diagram showing variation in yield and composition of milk of cow No. 205 at end of each 4-week period.

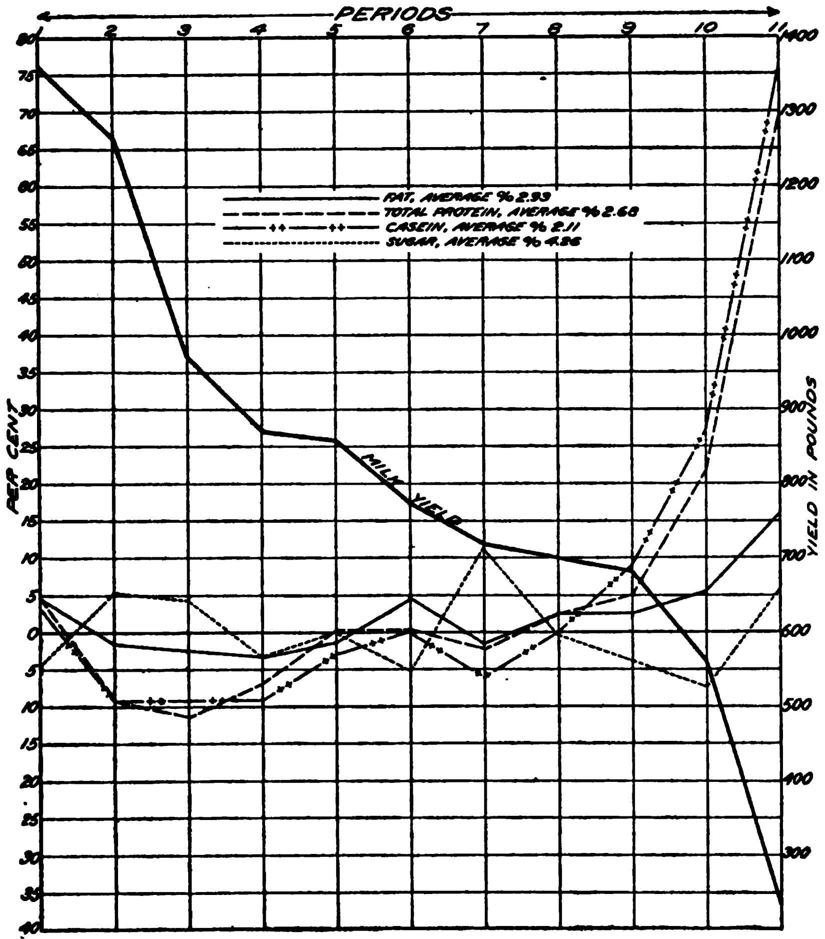

Fig. 5.—Diagram showing variation in yield and composition of milk of cow No. 206 at end of each 4-week period.

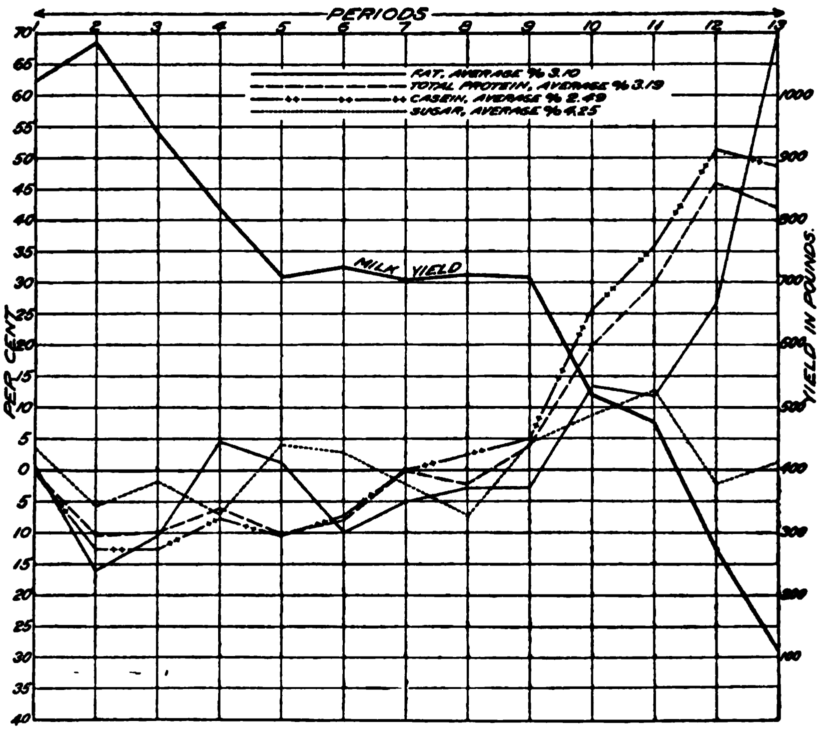

FIG. 6.—Diagram showing variation in yield and composition of milk of cow No. 209 at end of each 4-week period.

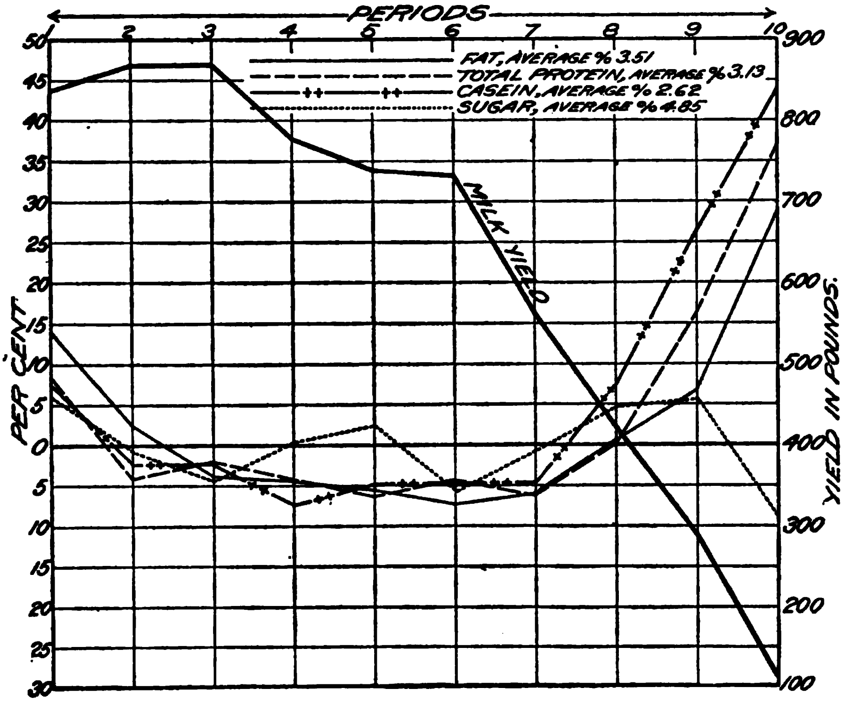

FIG. 7.—Diagram showing variation in yield and composition of milk of cow No. 300 at end of each 4-week period.

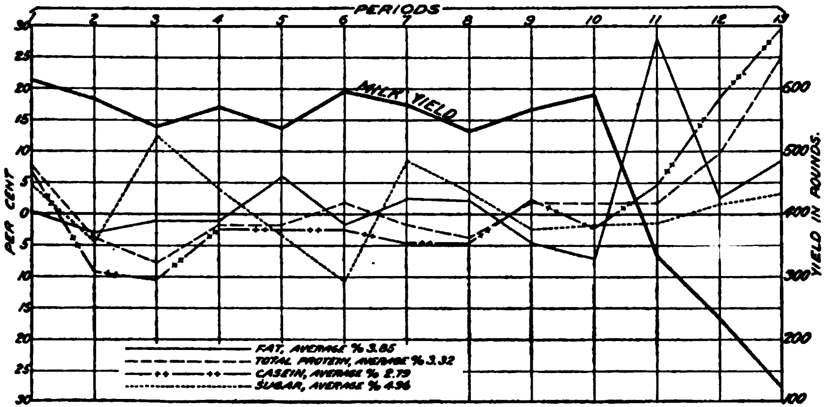

FIG. 8.—Diagram showing variation in yield and composition of milk of cow No. 301 at end of each 4-week period.

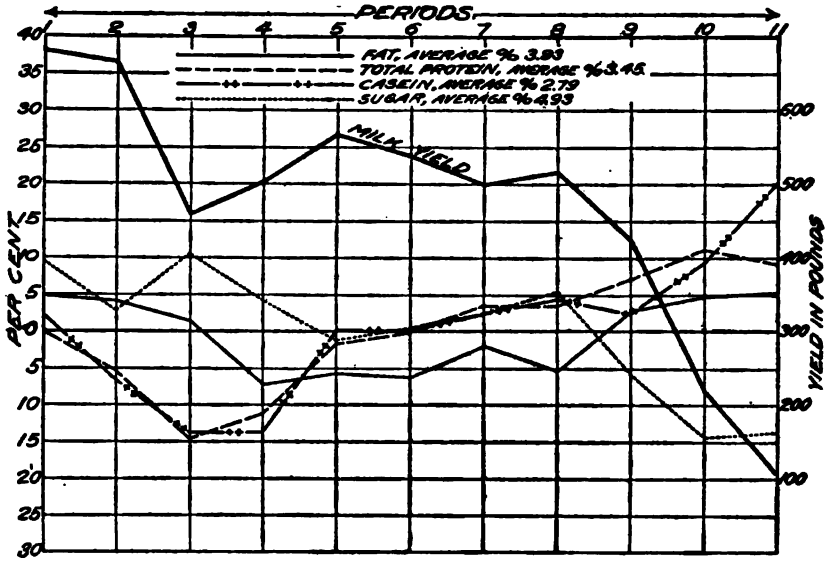

FIG. 9.—Diagram showing variation in yield and composition of milk of cow No. 400 at end of each 4-week period.

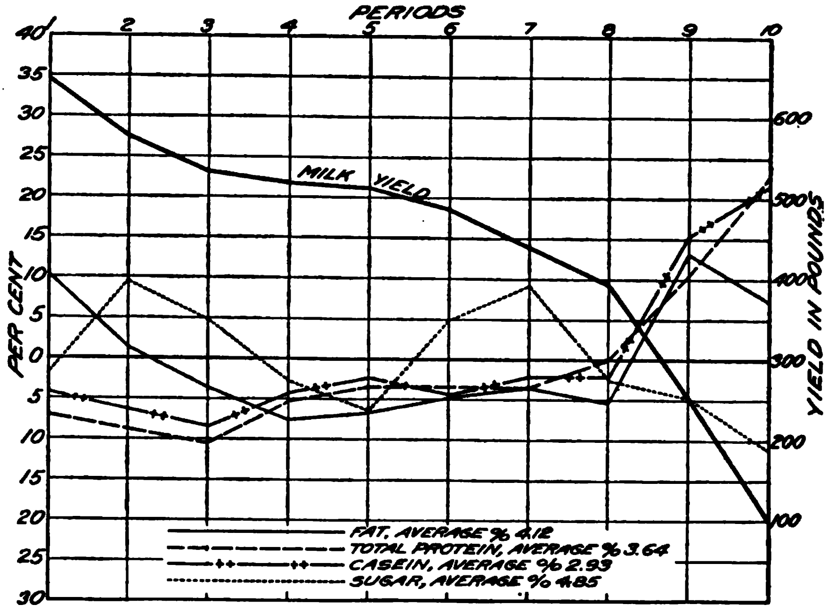

FIG. 10.—Diagram showing variation in yield and composition of milk of cow No. 402 at end of each 4-week period.

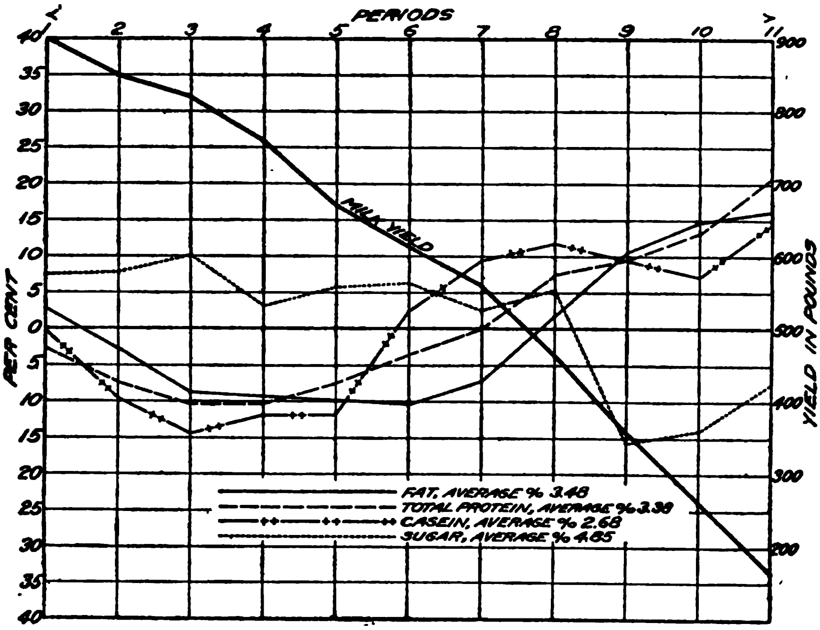

FIG. 11.—Diagram showing variation in yield and composition of milk of cow No. 403 at end of each 4-week period.

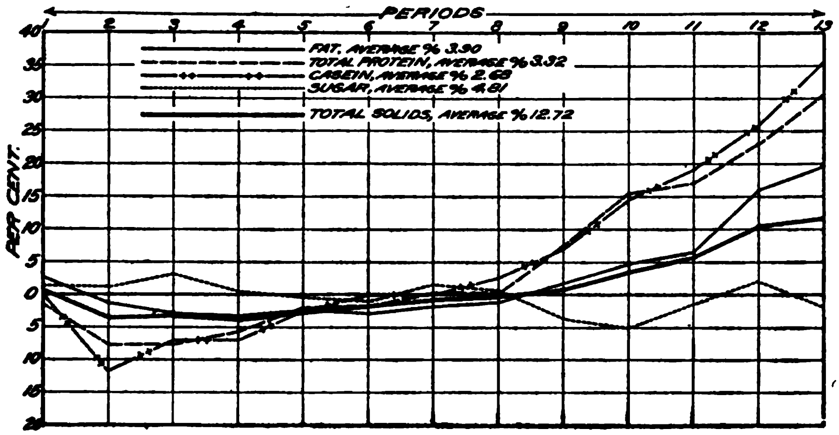

FIG. 12.—Diagram showing variation in yield and composition of milk at end of each 4-week period; average for 11 cows.

It is a well-established fact that the milk secreted immediately after parturition is abnormally high in albumin. But it is not generally understood that this is also true, although in lesser measure, of the other milk proteids, and that the normal per cent of this constituent is not reached for several weeks. The change in total nitrogen during the first 6 weeks is shown in Table 7. It must be borne in mind in studying this table that all analyses are made from what would be generally considered normal milk. In no case were the samples taken until the colostrum period was passed; therefore we can not ascribe the high total nitrogen content during the first few weeks to the high albumin content of the colostrum. It will be noted that in every case but one the per cent of nitrogen starts high, drops decidedly the second week, and reaches the lowest point in from 4 to 6 weeks.

After the lowest point is reached the per cent of total nitrogen remains fairly constant until about the eighth month of the lactation period, when it begins to rise gradually. Toward the end of the period it rises more rapidly until it attains its maximum at the end of the lactation period. The range of variation with individual cows and with the average is shown below.

	Low.	Average.	High.
Maximum range in per cent of total protein	2.36	2.68	4.53
Minimum range in per cent of total protein	3.32	3.70	4.21
Average (11 cows)	2.97	3.30	4.31

If we express the average total protein by 100 per cent the variation will be as follows:

	Low.	Average.	High.	Total range in per cent of average protein.
Maximum range	88.0	100	169.0	81.0
Minimum range	89.7	100	113.7	24.0
Average (11 cows)	90.0	100	130.6	40.6

The data show a wide range of variation in total protein during the normal lactation period. As compared with the fat, generally assumed to be the most valuable constituent, it will be found with the 11 cows used in this investigation that the variation in total protein exceeds the variation in fat. This is shown in figure 12. However, if the composition of the milk of each separate milking was known it is quite certain from other data at hand that the range of variation in the per cent of fat would be much greater than with the casein; that is to say, the fat varies more from milking to milking than does the total nitrogen; but eliminating these temporary variations the per cent of fat is less affected by the period of lactation than is the total nitrogen.

It might be mentioned at this point that the last samples included were still what would be considered as normal milk. In some instances analyses were made on samples taken up to the time that the cows ceased to produce milk, but these results are not included in the tables.

TABLE 6.—*Average total nitrogen for each cow and average total nitrogen and protein for each breed, by 4-week periods.*

Cow No.	First period.	Second period.	Third period.	Fourth period.	Fifth period.	Sixth period.	Seventh period.	Eighth period.	Ninth period.	Tenth period.	Eleventh period.	Twelfth period.	Thirteenth period.	Fourteenth period.
	P.ct.	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*
4	0.52	0.53	0.57	0.61	0.60	0.59	0.59	0.57	0.62	0.66	.....	.....	.....	.....
99	.51	.51	.51	.49	.49	.49	.48	.50	.52	.56	0.62	0.66	.....	.....
118	.....	.51	.56	.54	.65	.65	.67	.64	.64	.64	.65	.70	0.75	0.77
Average total nitrogen for Jerseys	.52	.52	55	.55	.58	.58	.58	.57	.59	.62	.64	.68	.....	.....
Average total protein for Jerseys	3.32	3.32	3.51	3.51	3.70	3.70	3.70	3.64	3.76	3.96	4.08	4.34	.....	.....
205	.49	.43	.44	.44	.45	.45	.45	.44	.48	.48	.51	.55	.59	.65
206	.44	.38	.37	.39	.42	.42	.41	.43	.44	.51	.71	.....	.....	.....
209	.50	.45	.45	.47	.45	.46	.50	.49	.52	.60	.65	.73	.71	.....
Average total nitrogen for Holsteins	.48	.42	.42	.43	.44	.44	.45	.45	.48	.53	.62	.64	.65	.....
Average total protein for Holsteins	3.06	2.68	2.68	2.74	2.81	2.81	2.87	2.87	3.06	3.38	3.96	4.08	4.15	.....
300	.53	.47	.48	.47	.46	.47	.46	.48	.57	.67	.....	.....	.....	.....
301	.56	.50	.48	.51	.51	.53	.51	.50	.53	.53	.53	.57	.65	.....
Average total nitrogen for Ayrshires	.55	.49	.48	.49	.49	.50	.49	.50	.55	.60	.....	.....	.....	.....
Average total protein for Ayrshires	3.51	3.13	3.06	3.13	3.13	3.19	3.13	3.19	3.51	3.83	.....	.....	.....	.....
400	.54	.51	.46	.48	.53	.54	.56	.56	.58	.60	.59	.....	.....	.....
402	.53	.52	.51	.54	.55	.55	.55	.57	.63	.70	.....	.....	.....	.....
403	.52	.49	.47	.47	.49	.51	.53	.57	.58	.60	.64	.....	.....	.....
Average total nitrogen for Shorthorns	.53	.51	.48	.50	.52	.53	.55	.57	.60	.63	.62	.....	.....	.....
Average total protein for Shorthorns	3.38	3.25	3.06	3.19	3.32	3.38	3.51	3.64	3.83	4.02	3.96	.....	.....	.....
Grand average total nitrogen	.51	.48	.48	.49	.51	.51	.52	.52	.56	.60	.61	.64	.68	.64
Grand average total protein	3.25	3.06	3.06	3.13	3.25	3.25	3.32	3.32	3.57	3.83	3.89	4.08	4.34	.....
Variation in percentage of total protein, on basis of first period being 100 per cent	100	94	94	96	100	100	102	102	110	118	120	125	133	.....

TABLE 7.—*Showing change in the total nitrogen of each cow during the first 6 weeks.*

Week.	Cow No. 4.	Cow No. 99.	Cow No. 205.	Cow No. 206.	Cow No. 209.	Cow No. 300.	Cow No. 301.	Cow No. 400.	Cow No. 402.	Cow No. 403.
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
1	0.52	0.55	0.54	0.53	0.61	0.61	0.64	0.57	0.58	0.57
2	.52	.52	.51	.43	.49	.53	.57	.54	.51	.51
3	....	.51	.46	.40	.44	.50	.54	.53	.51	.51
4	....	.46	.46	.39	.45	.48	.50	.53	.52	.50
5	.57	.51	.44	.37	.45	.46	.49	.51	.50	.51
6	.49	.52	.43	.38	.43	.46	.50	.52	.52	.48

It is believed this change in the per cent of total nitrogen during the lactation period, as shown by the data given, is entirely normal. Every cow, with one exception, showed a decline during the first few weeks, and all showed a rise in the latter end of the period, although with some this was much more marked than with others.

The authors suggest that this normal decline in total protein in the early part of the lactation period is due to the physical condition of the animal. Under normal conditions a cow is in a good physical condition at calving time. That is to say, she has been on a high plane of nutrition and has stored surplus fat and protein in the body. This is a provision of nature to prepare the animal to produce milk for her young, if necessary partly at the expense of her own body.

After calving, under normal conditions, the cow loses in weight for from 2 to 10 weeks. This means that she does not consume sufficient food to furnish maintenance and support the milk production. Consequently, she draws for some time on her stored nutrients and loses weight. This loss of weight happened with the 11 cows used in the investigation here reported. Perhaps on the average the decline in weight was rather more than the normal. Unfortunately, no complete records of weight were kept.

However, by referring to Tables 27 and 28 data may be studied that bear directly upon this problem. The 5 cows dealt with in these tables were used in another investigation in which it was an important part of the plan to maintain a uniform weight throughout the milking period. The weights given are the averages of daily weight for the period included. It will be observed that except in the case of No. 27 practically uniform weights were maintained. No. 27, on account of the large amount of milk produced and because she suffered from some indigestion, lost weight rapidly during the first 10 days. The total nitrogen in her milk was also low at this stage and, in fact, follows her decrease and increase in weight in general throughout the milking period. The other 4 cows were maintained at practically the same weight throughout the entire milking period, and it will be observed that the per cent of total nitrogen is almost constant. It should be understood that these cows were farrow, which may account for the fact that there was no marked increase in the total nitrogen in the last part of the lactation period, but it does not account for the fact that there was no decline in the first few weeks.

CASEIN NITROGEN AND CASEIN.

Table 8 gives the casein nitrogen by 4-week periods for each cow, with an average for each breed and for the 11 cows. The averages are also expressed in casein found by using the factor 6.38.

The variations in the casein nitrogen during the lactation period are similar to those of the total nitrogen. There is the same decline during the first few weeks, followed by a gradual rise lasting from 5 to 8 months, then a more rapid increase to the end of the period.

The range of variations in casein content with individual cows and with the average is shown below:

	Low.	Average.	High.
Maximum range in per cent casein	2.04	3.14	3.89
Minimum range in per cent casein	2.30	2.61	3.06
Average (11 cows)	2.32	2.68	3.56

If we express the average casein content by 100 per cent, the maximum and minimum would be as follows:

	Low.	Average.	High.	Total range in per cent of average casein.
Maximum range	64.9	100	123.8	58.9
Minimum range	88.1	100	117.2	29.0
Average (11 cows)	86.5	100	130.0	45.5

The maximum range of variation is 1.85 per cent of casein, or 58.9 per cent of the average casein content; the minimum is 29.1 per cent of the average; while the 11 cows show an average variation of 1.21 per cent, or 45.5 of the average casein content. It will be noted that the maximum range is caused by one exceptionally low figure, while the high point reached by the same animal is closer to her average than is the case with the average figures for the 11 cows.

It will be further noted that with the average figures the minimum figure is only 0.36 per cent below the mean, while the maximum is 0.88 above. The greater variation in the latter is due to the exceedingly high figures reached at the end of the lactation period.

TABLE 8.—*Average casein nitrogen for each cow, and breed average, and average casein nitrogen and casein for each breed, by 4-week periods.*

Cow No.	First period.	Second period.	Third period.	Fourth period.	Fifth period.	Sixth period.	Seventh period.	Eighth period.	Ninth period.	Tenth period.	Eleventh period.	Twelfth period.	Thirteenth period.	Fourteenth period.
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
4	0.44	0.38	0.48	0.49	0.48	0.47	0.47	0.46	0.50	0.52	.....	.....	.....	.....
99	.42	.41	.40	.40	.40	.40	.39	.40	.42	.46	0.51	0.53	.....	.....
118	.....	.32	.48	.42	.54	.52	.54	.54	.51	.50	.51	.55	0.61	0.58
Average casein nitrogen for Jerseys	.43	.37	.45	.44	.47	.47	.47	.47	.48	.49	.51	.54	.....	.....
Average casein for Jerseys	2.74	2.36	2.87	2.81	3.00	3.00	3.00	3.00	3.06	3.13	3.25	3.45	.....	.....
205	.40	.35	.34	.36	.37	.38	.37	.37	.38	.39	.43	.45	.51	.57
206	.34	.30	.29	.30	.32	.33	.31	.33	.36	.42	.58	.....	.....	.....
209	.39	.34	.34	.36	.35	.36	.39	.40	.41	.49	.53	.59	.58	.....
Average casein nitrogen for Holsteins	.38	.33	.32	.34	.35	.36	.36	.37	.38	.43	.51	.52	.55	.....
Average casein for Holsteins	2.42	2.11	2.04	2.17	2.23	2.30	2.30	2.36	2.42	2.74	3.25	3.32	3.51	.....
300	.44	.40	.40	.38	.39	.39	.39	.44	.52	.59	.....	.....	.....	.....
301	.47	.40	.39	.43	.43	.43	.42	.42	.45	.43	.46	.52	.57	.....
Average casein nitrogen for Ayrshires	.46	.40	.40	.41	.41	.41	.41	.43	.49	.51	.....	.....	.....	.....
Average casein for Ayrshires	2.93	2.55	2.55	2.62	2.62	2.62	2.62	2.74	3.13	3.25	.....	.....	.....	.....
400	.45	.41	.38	.38	.44	.44	.45	.46	.45	.48	.53	.....	.....	.....
402	.44	.43	.42	.44	.45	.44	.45	.45	.53	.56	.....	.....	.....	.....
403	.42	.38	.36	.37	.37	.43	.46	.47	.46	.45	.48	.....	.....	.....
Average casein nitrogen for Shorthorns	.44	.41	.39	.40	.42	.44	.45	.46	.48	.50	.51	.....	.....	.....
Average casein for Shorthorns	2.81	2.62	2.49	2.55	2.68	2.81	2.87	2.93	3.06	3.19	3.25	.....	.....	.....
Grand average casein nitrogen	.42	.37	.39	.39	.41	.42	.42	.43	.45	.48	.50	.53	.57	.58
Grand average casein	2.68	2.36	2.49	2.49	2.62	2.68	2.68	2.74	2.87	3.06	3.19	3.38	3.64	3.70
Variation in percentage of casein on basis of first period being 100 per cent	100	88	93	93	98	100	100	102	107	114	119	126	136	138

Table 9 gives the ratio of casein nitrogen to total nitrogen for each animal. A striking uniformity will be observed in this table. From 79 to 83 per cent of the total nitrogen consists of casein in most cases. This ratio shows but little change even when the total protein makes a wide variation.

Table 10 shows this relation by weeks for the first 5 and the last 5 weeks of the lactation period. The milk at these two extremes of the milking period shows the widest variation in composition, but it will be noted the ratio between the total nitrogen and the casein remains practically unaffected. For example, cow No. 206 in the third period averaged 0.29 per cent total nitrogen, of which 78 per cent was casein. In her eleventh period she averaged 0.58 per cent total nitrogen, or exactly double that of the third period, of which 82 per cent was casein. There seems to be only a slight effect that can be attributed to the advance in the period of lactation, and that is a small increase in the relative amount of casein in the last part of the lactation period, when the per cent of total protein increases very rapidly.

TABLE 9.—*Average ratio of casein nitrogen to total nitrogen, by 4-week periods.*

Cow No.	First period.	Second period.	Third period.	Fourth period.	Fifth period.	Sixth period.	Seventh period.	Eighth period.	Ninth period.	Tenth period.	Eleventh period.	Twelfth period.	Thirteenth period.	Fourteenth period.
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
4	0.85	0.72	0.84	0.80	0.80	0.81	0.80	0.81	0.81	0.79	.....	.....	.....	.....
99	.82	.80	.78	.82	.82	.82	.81	.80	.81	.82	0.82	0.80	.....	.....
118	.....	.63	.86	.78	.83	.80	.81	.84	.80	.78	.79	.79	0.81	0.75
Average for Jerseys	.84	.72	.83	.80	.82	.81	.81	.82	.81	.80	.81	.80	.81	.75
205	.82	.81	.77	.82	.82	.84	.82	.84	.79	.81	.84	.82	.86	.88
206	.77	.79	.78	.77	.76	.79	.76	.77	.82	.82	.82	.....	.....	.....
209	.78	.76	.76	.77	.78	.78	.78	.82	.79	.82	.82	.81	.82	.....
Average for Holsteins	.79	.79	.77	.79	.79	.80	.79	.81	.80	.82	.83	.82	.84	.88
300	.83	.85	.83	.81	.85	.83	.85	.90	.91	.88	.....	.....	.....	.....
301	.84	.80	.81	.84	.84	.81	.82	.84	.85	.81	.87	.91	.88	.....
Average for Ayrshires	.84	.83	.82	.83	.85	.82	.84	.87	.88	.85	.87	.91	.88	.....
400	.83	.80	.83	.79	.83	.82	.80	.82	.78	.80	.90	.....	.....	.....
402	.83	.88	.82	.82	.82	.80	.82	.79	.84	.80	.....	.....	.....	.....
403	.81	.78	.77	.79	.76	.84	.87	.83	.79	.75	.75	.....	.....	.....
Average for Shorthorns	.82	.80	.81	.80	.80	.82	.83	.81	.80	.78	.83	.....	.....	.....
Grand total average	.82	.78	.80	.80	.81	.81	.81	.82	.82	.81	.83	.83	.84	.82

TABLE 10.—*Ratio of casein nitrogen to total nitrogen for each cow for first 5 and last 5 weeks of lactation period.*

Stage.	Cow No.—										
	4	99	118	205	206	209	300	301	400	402	403
First week	0.88	0.78	......	0.80	0.77	0.75	0.80	0.83	0.82	0.83	0.81
Second week	......	.85	......	.80	.79	.80	.83	.86	.83	.84	.84
Third week	......	.78	......	.83	.78	.77	.86	.85	.85	.82	.76
Fourth week	......	.91	......	.80	.77	.80	.83	.82	.79	.88	.76
Fifth week	......	.80	......	.80	.81	.76	.87	.84	.80	.84	.72
Fifth week from end	.79	.75	0.79	.82	.79	.79	.91	.95	.82	.81	.73
Fourth week from end	.80	.83	.78	.89	.80	.85	.90	.90	.84	.86	.75
Third week from end	.76	.83	.81	.90	.79	.78	.89	.92	.90	.59	.73
Second week from end	.78	.78	.71	.89	.85	.84	.86	.85	.86	.89	.74
Last week	.79	.79	.75	.85	.79	.79	.85	.87	.93	.92	.77

ALBUMIN.

Table 11 shows the amount of nitrogen as albumin. The average for the breeds and the grand average is also expressed as albumin by using the factor 6.38. The nitrogen as albumin was determined as already stated by the provisional method of coagulating the filtrate from the casein-nitrogen determination by heat and finding the amount of nitrogen in the residue by the Gunning method. This method has proved unsatisfactory, failing to yield concordant results even when the greatest of care is used in carrying it out. This is no doubt due to the similarity of the albumin and the remaining soluble proteins. It is impossible with the provisional method to separate the albumin from the remaining protein with any degree of accuracy. This probably accounts for some of the extreme variations found in the results here reported.

TABLE 11.—*Average albumin nitrogen and albumin, by 4-week periods.*

Cow No.	First period.	Second period.	Third period.	Fourth period.	Fifth period.	Sixth period.	Seventh period.	Eighth period.	Ninth period.	Tenth period.	Eleventh period.	Twelfth period.	Thirteenth period.	Fourteenth period.
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
4	0.059	0.056	0.057	0.067	0.045	0.031	0.064	0.061	0.062	0.063	.....	.....	.....	.....
99	.038	.054	.037	.025	.029	.043	.036	.041	.035	.043	0.042	0.071	.....	.....
118	.....	.081	.051	.057	.074	.071	.049	.057	.062	.069	.062	.065	0.061	0.062
Average albumin nitrogen for Jerseys	.049	.064	.048	.050	.049	.048	.050	.053	.053	.058	.052	.068	.....	.....
Average albumin for Jerseys	.313	.408	.306	.319	.313	.306	.319	.338	.338	.370	.332	.434	.....	.....
205	.041	.032	.031	.032	.034	.032	.037	.036	.027	.032	.035	.038	.025	.027
206	.042	.028	.030	.022	.028	.034	.040	.036	.036	.039	.065	.....	.....	.....
209	.051	.032	.037	.038	.034	.042	.044	.047	.038	.057	.063	.084	.067	.....
Average albumin nitrogen for Holsteins	.045	.031	.033	.031	.032	.036	.040	.040	.034	.043	.054	.041	.031	.....
Average albumin for Holsteins	.287	.198	.211	.198	.204	.230	.255	.255	.217	.274	.345	.262	.198	.....
300	.039	.031	.027	.030	.031	.029	.029	.019	.017	.032	.....	.....	.....	.....
301	.043	.032	.042	.035	.042	.046	.043	.036	.033	.036	.033	.024	.032	.....
Average albumin nitrogen for Ayrshires	.041	.032	.035	.033	.037	.038	.036	.028	.025	.034	.....	.....	.....	.....
Average albumin for Ayrshires	.262	.204	.223	.211	.236	.242	.230	.179	.160	.217	.....	.....	.....	.....
400	.055	.053	.033	.043	.045	.043	.057	.046	.046	.038	.027	.....	.....	.....
402	.051	.049	.047	.046	.045	.045	.042	.042	.055	.029	.....	.....	.....	.....
403	.053	.051	.043	.044	.045	.033	.030	.045	.067	.093	.092	.....	.....	.....
Average albumin nitrogen for Shorthorns	.053	.051	.041	.044	.045	.040	.043	.044	.056	.053	.060	.....	.....	.....
Average albumin for Shorthorns	.338	.325	.262	.281	.287	.255	.274	.281	.357	.338	.383	.....	.....	.....
Grand average albumin nitrogen	.047	.045	.040	.040	.041	.042	.043	.042	.044	.048	.052	.056	.046	.045
Grand average albumin	.300	.287	.255	.255	.262	.268	.274	.268	.281	.306	.332	.357	.293	.287
Variation in percentage of albumin, on basis of first period being 100 per cent	100	95	85	85	87	89	91	89	93	102	111	119	97	96

Since the figures given in Table 11 are in each case the average of 4 samples each representing one week, the extreme variations which occur in the weekly tables given in the appendix and which it is recognized are due in part to the method used, are largely removed, and it is possible to study the general effect of the lactation period on the albumin nitrogen.

The albumin nitrogen follows the same course as the casein nitrogen during the lactation period. In the beginning it is higher than the average, soon declines, reaching the minimum about the third month.

From this point on there is a gradual rise, which becomes much more pronounced at the end. The range in albumin by individual animals in 4-week periods is as follows:

	Low.	Average.	High.
Maximum range in per cent albumin	0.191	0.310	0.593
Minimum range in per cent albumin	.159	.218	.268
Average (11 cows)	.181	.279	.405

If we express the average albumin by 100, the results given above would be as follows:

	Low.	Average.	High.	Total range in per cent average albumin.
Maximum range	61.6	100	191.2	130.0
Minimum range	74.6	100	123.0	48.4
Average range (11 cows)	64.8	100	145.1	80.3

Table 12 shows the ratio of albumin to total nitrogen. It will be observed that, like the casein nitrogen, the albumin nitrogen bears a definite relation to the total nitrogen. This table shows the albumin nitrogen to constitute on the average 8.1 per cent of the total, and the only variation in this ratio that can be attributed to the period of lactation is the somewhat smaller proportion of albumin in the last 3 or 4 week periods.

TABLE 12.—*Relation of the casein, albumin, and residual nitrogen to the total nitrogen, by 4-week periods.*

Period No.	Total nitrogen.	Casein nitrogen.	Albumin nitrogen.	Residual nitrogen.	Period No. No.	Total nitrogen.	Casein nitrogen.	Albumin nitrogen.	Residual nitrogen.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
1	100	82	9	9	9	100	82	8	10
2	100	78	9	13	10	100	81	8	11
3	100	80	8	12	11	100	83	9	8
4	100	80	8	12	12	100	83	9	8
5	100	81	8	11	13	100	84	7	9
6	100	81	8	11	14	100	82	6	12
7	100	81	8	11					
8	100	82	8	10	Average	100	81.4	8.1	11

THE RESIDUAL NITROGEN.

Under this term as here used is included the nitrogen remaining in solution after that precipitated as albumin is removed by filtering. The chemical nature of the nitrogen compounds included in this group will not be considered.

Below is given the average residual nitrogen for the 11 cows by 4-week periods:

	Period.											
	1	2	3	4	5	6	7	8	9	10	11	12
Per cent residual nitrogen..	0.046	0.062	0.053	0.058	0.055	0.056	0.054	0.060	0.058	0.066	0.056	0.058

It will be observed that this amount does not show any variation that can be ascribed to the period of lactation. The total amount is slightly more than that classed as albumin.

RATIO OF PROTEINS TO OTHER CONSTITUENTS.

Table 12 also gives a summary of the relation of the casein nitrogen, albumin nitrogen, and residual nitrogen to the total nitrogen. On the average 81.4 per cent of the total nitrogen is present as casein, and, as already pointed out, this ratio shows but little variation during the lactation period. The nitrogen determined as albumin varies from 7 to 9 per cent of the total and the residual nitrogen averages 11 per cent of the total.

Table 13 shows the relation between the total protein and the sugar. We find that the ratio of the sugar to the total protein increases during the first 10 or 12 weeks, reaching the maximum, as a rule, in the third month. From this period there is little change until the ninth month, when the ratio rapidly becomes narrower to the end of the period. This change is brought about by the fact that the per cent of sugar remains practically constant, while the total protein changes considerably during the lactation period. The data given indicate that the per cent of sugar does not follow the variation of the nitrogen and seems to bear no special relation to it. On the average there is found 1.45 pounds of sugar for each pound of protein.

TABLE 13.—*Average ratio of sugar to total protein, by 4-week periods.*

Period.	Total protein.	Sugar.				
		Average for 3 Jerseys.	Average for 3 Holsteins.	Average for 2 Ayrshires.	Average for 3 Shorthorns.	Average for 11 cows.
1......	1.00	1.50	1.44	1.47	1.52	1.47
2......	1.00	1.48	1.69	1.54	1.60	1.58
3......	1.00	1.41	1.69	1.68	1.74	1.62
4......	1.00	1.43	1.61	1.61	1.57	1.55
5......	1.00	1.37	1.67	1.58	1.40	1.50
6......	1.00	1.34	1.62	1.35	1.49	1.46
7......	1.00	1.29	1.64	1.65	1.46	1.50
8......	1.00	1.39	1.50	1.62	1.39	1.46
9......	1.00	1.23	1.49	1.42	1.17	1.32
10......	1.00	1.22	1.36	1.24	1.06	1.22
11......	1.00	1.22	1.24	1.45	1.11	1.23
12......	1.00	1.19	1.16	1.39	....	1.22
13......	1.00	....	1.13	....	....	1.13

FAT.

Table 14 gives the per cent of fat for each cow by 4-week periods, and the same is shown graphically in figures 1 to 11. Figure 12 indicates the average change in the per cent of fat for the 11 cows. An examination of the weekly tables in the appendix will show wide variations with individuals and at different periods. Leaving these minor variations out of consideration, the normal variation during the lactation period may be studied.

The data in the table show that there is a decline in fat during the first 3 months, followed by a period of from 4 to 5 months with little change. From this point on to the end of the lactation period the fat increases rapidly, reaching the maximum at the close. The results from practically every cow agree with this general statement. It is generally recognized that as a rule the milk becomes richer in fat toward the end of the lactation period, but an error is commonly made in assuming that this change is a gradual one from near the beginning of the milking period. On the contrary, there is little increase in the per cent of fat as a rule until that period is reached—ordinarily within 2 months of the end of the lactation period—when a rapid decline begins in the quantity of milk produced.

There are several factors that influence the per cent of fat in milk as consistently as does the stage of the lactation period, and these factors may even entirely overbalance the usual effect of advancing lactation. One of the authors has recently called attention to two factors that have such an influence. One of these is a variation that occurs with the season,[1] which tends, in this climate at least, to cause a low per cent of fat in the middle of the summer and a higher in early winter regardless of the date of the beginning of the lactation period. The other is the influence of the physical condition of the animal.[2] If the animal carries a large amount of body fat at calving time, her milk during the first few weeks, when the body weight is declining from the absorption of fat from the body, will contain more than the normal amount of fat for that particular animal. This latter is probably the explanation of the decline in fat observed in Table 14, which gives the results for the 11 cows used in this investigation.

There is in general some relation between the amount of milk and the per cent of fat. When there is a sudden decline in the amount of milk secreted for any reason, as, for example, during sickness or on account of the animal having been moved to strange surroundings, the per cent of fat with few exceptions increases sharply. The same holds true in the rapid decline that occurs in the last portion of the lactation period. When the decline in milk secreted is gradual, as is the case during the middle part of the lactation period, there is no special tendency for the per cent of fat to increase. However, while it is safe to make this general statement concerning the influence of the period of lactation when conditions are normal and when a sufficient number of animals are included to eliminate minor variations, it must be borne in mind that individual animals such as are found in commercial dairies may diverge widely from this general rule owing to other factors or combinations of factors which exert a greater influence.

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[1] Eckles, C. H. Jahreszeitliche Schwankungen des prozentischen Fettgehaltes in Kuhmilch. Milchwirtschaftliches Zentralblatt, vol. 5, No. 11, pp. 488-502. Leipzig, November, 1909.

[2] Eckles, C. H. The influence of the fatness of cow at parturition on per cent of fat in milk. Missouri Experiment Station Bulletin 100. Columbia, Mo., 1912.

TABLE 14.—*Average per cent of fat for each cow, and breed average, by 4-week periods.*

Cow No.	First period.	Second period.	Third period.	Fourth period.	Fifth period.	Sixth period.	Seventh period.	Eighth period.	Ninth period.	Tenth period.	Eleventh period.	Twelfth period.	Thirteenth period.	Fourteenth period.
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
4	5.17	4.63	5.07	4.85	4.81	5.00	4.73	4.51	4.73	5.18	.....	.....	.....	.....
99	5.22	4.79	4.43	4.40	4.33	4.22	4.36	4.18	4.63	4.98	5.62	6.07	.....	.....
118	.....	5.31	5.55	5.11	5.51	5.71	5.69	5.80	5.17	4.47	4.83	5.28	5.48	6.47
Average for Jerseys	5.20	4.91	5.02	4.79	4.88	4.98	4.93	4.83	4.84	4.88	5.23	5.68	5.48	6.47
205	3.24	3.14	3.02	3.25	3.29	3.06	3.26	3.25	3.15	3.31	3.31	3.49	3.68	3.68
206	3.07	2.88	2.58	2.84	2.89	3.06	2.88	3.00	3.00	3.09	3.40	.....	.....	.....
209	3.12	2.60	2.74	3.24	3.14	2.81	2.94	3.01	3.01	3.52	3.46	3.90	5.28	.....
Average for Holsteins	3.14	2.87	2.78	3.11	3.11	2.98	3.03	3.09	3.05	3.31	3.39	3.70	4.48	3.68
300	4.01	3.61	3.38	3.36	3.32	3.26	3.30	3.53	3.74	4.52	.....	.....	.....	.....
301	3.87	3.74	3.81	3.81	4.08	3.78	3.95	3.94	3.67	3.58	4.92	3.96	4.18	.....
Average for Ayrshires	3.94	3.68	3.60	3.59	3.70	3.52	3.63	3.74	3.71	4.05	4.92	3.96	4.18	.....
400	4.12	4.09	3.99	3.65	3.70	3.69	3.85	3.73	4.05	4.16	4.17	.....	.....	.....
402	4.55	4.17	3.97	3.80	3.84	3.92	3.98	3.90	4.67	4.42	.....	.....	.....	.....
403	3.58	3.38	3.18	3.16	3.14	3.13	3.23	3.55	3.85	4.00	4.05	.....	.....	.....
Average for Shorthorns	4.08	3.88	3.71	3.54	3.56	3.58	3.69	3.73	4.19	4.19	4.11	.....	.....	.....
Grand total average	4.00	3.85	3.79	3.77	3.82	3.79	3.83	3.85	3.97	4.11	4.22	4.54	4.66	5.08

RELATION OF FAT TO OTHER CONSTITUENTS.

An examination of the data and the curves will show a similarity between the variation in the total protein and in the fat. While sudden variations in fat content from one milking to another are not accompanied by corresponding variations in the total protein, yet when the fat is permanently increased the protein is almost certain to be increased in the same proportion. While the ratio of fat to protein varies with individuals and breeds, it varies but little with the same individual from month to month.

Table 15 is a summary of the influence of the stage of lactation on the fat, and the relation of the fat to total protein and casein. It will be observed that this ratio is fairly uniform. As compared to the average the total protein, as well as the casein, is low in the beginning in proportion to the fat, and increases gradually until it reaches the maximum near the end of the lactation period. This results from the fact that the total protein increases more during the progress of the lactation period, especially during the last four months, than does the fat. On the average there is 0.86 pound of total protein and 0.71 pound of casein for each pound of fat. This relation is of interest in connection with the buying of milk for cheese making and the use of milk for food. Figure 12 shows that the total protein is influenced more by the stage of lactation than is the fat. Even at the end of the lactation period the per cent of fat on the average is only 20 per cent above the mean, while the total protein increases to 30 per cent above the mean.

TABLE 15.—*Relation of total protein and casein to fat, averaged by 4-week periods.*

Period.	Fat.	Total protein.	Casein.	Parts protein for 1 part fat.	Parts casein for 1 part fat.	Period.	Fat.	Total protein.	Casein.	Parts protein for 1 part fat.	Parts casein for 1 part fat.
	Per ct.	*Per ct.*	*Per ct.*				*Per ct.*	*Per ct.*	*Per ct.*		
1	4.00	3.25	2.68	0.81	0.67	9	3.97	3.57	2.87	0.90	0.72
2	3.85	3.06	2.36	.79	.61	10	4.11	3.83	3.06	.93	.74
3	3.79	3.06	2.49	.81	.66	11	4.22	3.89	3.19	.92	.76
4	3.77	3.13	2.49	.83	.66	12	4.54	4.08	3.38	.90	.74
5	3.82	3.25	2.62	.85	.69	13	4.66	4.34	3.64	.93	.78
6	3.79	3.25	2.68	.86	.71	14	5.08	4.08	3.70	.80	.73
7	3.83	3.32	2.68	.87	.70						
8	3.85	3.32	2.74	.86	.71	Average.	4.09	3.53	2.90	.86	.71

Table 16 shows the relation between the fat and the sugar as influenced by the stage of lactation. It will be observed that from the first period to the second and third there is some increase in the ratio. The columns giving the amount of sugar and fat, however, show that this is due not to an increase in the sugar but to a decrease in the fat.

The ratio remains practically the same from the second to the eighth period, after which it becomes considerably less, due to some decline in the amount of sugar and an increase in the per cent of fat.

Table 16.—*Relation of sugar to fat, averaged by 4-week periods.*

Period.	Fat.	Sugar.	Parts sugar for 1 part fat.
	Per cent.	*Per cent.*	
1	4.00	4.87	1.22
2	3.85	4.84	1.30
3	3.79	4.94	1.36
4	3.77	4.82	1.31
5	3.82	4.80	1.29
6	3.79	4.75	1.30
7	3.83	4.88	1.32
8	3.85	4.83	1.28
9	3.97	4.62	1.20
10	4.11	4.55	1.13
11	4.22	4.74	1.16
12	4.54	4.91	1.12
13	4.66	4.70	1.05
14	5.08	5.01	1.06
Average	4.09	4.80	1.22

The ratio existing between the fat and the total protein is summarized in Table 17.

Table 17.—*Ratio of fat to total protein, averaged by 4-week periods.*

Period.	Total protein.	Fat.				
		Average for 3 Jerseys.	Average for 3 Holsteins.	Average for 2 Ayrshires.	Average for 3 Shorthorns.	Average for 11 cows.
1	1.00	1.58	1.04	1.14	1.21	1.22
2	1.00	1.49	1.08	1.19	1.20	1.24
3	1.00	1.44	1.04	1.17	1.21	1.22
4	1.00	1.38	1.13	1.15	1.12	1.20
5	1.00	1.32	1.11	1.19	1.06	1.17
6	1.00	1.35	1.05	1.10	1.05	1.14
7	1.00	1.34	1.05	1.17	1.06	1.15
8	1.00	1.32	1.07	1.18	1.03	1.15
9	1.00	1.29	1.00	1.06	1.10	1.12
10	1.00	1.24	.984	1.06	1.04	1.08
11	1.00	1.29	.867	....	1.05	1.09
12	1.00	1.31	.917	....	....	1.11
13	1.00	....	1.07	....	....	1.07
14	1.00	....	....	....	....	....

SUGAR.

Table 18 gives the per cent of sugar by 4-week periods for each cow, also an average by breeds and for the 11 cows. The curves in figures 1 to 11 show the changes in the per cent of sugar for each animal individually, and figure 12 illustrates the average for all the cows. The statements made by various authorities that the sugar is the least variable of the milk constituents except the ash seems to be borne out by the data here presented. The per cent of sugar is strikingly uniform as compared with the protein and fat. The only change that can be observed that seems to be brought about by the stage of lactation is a slight decline during the last 3 or 4 months of the period. This decline is marked with some individuals, while others are uniform or even increase slightly. The general average as well as that for most of the individuals shows a slight decline, which seems sufficient to justify the general conclusion that the sugar runs practically uniform regardless of the period of lactation, excepting that a decline of from 0.2 to 0.4 per cent may be looked for in most cases during the last 3 or 4 months. The increase of the total solids is not sufficient to account for this decline. If the results are calculated on the basis of the water content the same small decline is found.

TABLE 18.—*Average percentage of sugar for each cow, and breed average, by 4-week periods.*

Cow No.	First period.	Second period.	Third period.	Fourth period.	Fifth period.	Sixth period.	Seventh period.	Eighth period.	Ninth period.	Tenth period.	Eleventh period.	Twelfth period.	Thirteenth period.	Fourteenth period.
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
4	4.89	4.99	4.87	5.28	5.12	5.00	4.39	4.45	4.67	4.60	.....	.....	.....	.....
99	4.94	5.15	5.17	5.05	5.04	4.50	4.52	5.14	4.62	5.03	5.02	5.61	.....	.....
118	.....	4.47	4.70	4.56	4.83	5.21	5.20	5.40	4.57	4.73	4.90	4.72	4.46	5.22
Average for Jerseys	4.92	4.87	4.91	4.96	5.00	4.90	4.70	5.00	4.62	4.79	4.96	5.17	4.46	5.22
205	4.69	4.98	4.84	5.18	5.42	5.37	5.20	4.76	5.10	5.12	5.13	5.02	4.89	4.81
206	4.07	4.49	4.44	4.12	4.26	4.04	4.74	4.25	4.09	3.94	4.50	.....	.....	.....
209	4.40	4.00	4.17	3.95	4.42	4.36	4.16	3.94	4.43	4.62	4.79	4.15	4.30	.....
Average for Holsteins	4.39	4.49	4.48	4.42	4.70	4.59	4.70	4.32	4.54	4.56	4.81	4.59	4.60	4.81
300	5.14	4.81	4.64	4.87	4.96	4.57	4.82	5.08	5.13	4.39	.....	.....	.....	.....
301	5.17	4.72	5.62	5.16	4.77	3.95	5.38	5.13	4.85	4.88	4.89	5.04	5.13	.....
Average for Ayrshires	5.16	4.77	5.13	5.02	4.87	4.26	5.10	5.11	4.99	4.64	4.89	5.04	5.13	.....
400	5.40	5.06	5.44	5.13	5.87	4.95	5.05	5.19	4.65	4.22	4.25	.....	.....	.....
402	4.77	5.32	5.09	4.72	4.55	5.09	5.29	4.73	4.61	4.31	.....	.....	.....	.....
403	5.21	5.22	5.39	5.00	4.58	5.16	4.98	5.11	4.08	4.17	4.47	.....	.....	.....
Average for Shorthorns	5.13	5.20	5.31	4.95	4.67	5.07	5.11	5.01	4.45	4.23	4.36	.....	.....	.....
Grand total average	4.87	4.84	4.94	4.82	4.80	4.75	4.88	4.83	4.62	4.55	4.74	4.91	4.50	5.01

TOTAL SOLIDS.

Table 19 gives the total solids. The stage of lactation causes much the same variation with the total solids as is found with the fat and protein. First, there is a decline of about one-half per cent from the first to the second month. From this time on to the eighth or ninth month there is little change. The rapid decline in milk during the last 3 months of the lactation period is accompanied by a marked increase in the total solids. This general statement holds good for each of the 11 animals used in the investigation.

TABLE 19.—*Average per cent of total solids, for each cow and breed average, by 4-week periods.*

Cow No.	First period.	Second period.	Third period.	Fourth period.	Fifth period.	Sixth period.	Seventh period.	Eighth period.	Ninth period.	Tenth period.	Eleventh period.	Twelfth period.	Thirteenth period.	Fourteenth period.
	P.ct.	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*
4	14.13	.....	.....	14.44	14.28	14.15	13.87	13.77	13.63	14.57	.....	.....	.....	.....
99	.....	13.09	13.30	13.15	12.92	12.76	13.04	12.81	13.35	14.27	15.15	16.08	.....	.....
118	.....	14.08	14.55	.....	.....	15.30	15.16	15.61	14.79	14.45	14.42	15.08	16.10	17.16
Average for Jerseys	14.13	13.59	13.93	13.80	13.60	14.07	14.02	14.06	13.92	14.43	14.79	15.58	16.10	17.16
205	11.74	11.58	11.70	11.95	12.11	11.77	11.98	12.16	11.95	12.12	12.20	12.50	13.04	13.42
206	10.95	10.10	10.18	10.27	10.54	10.73	10.75	10.80	11.01	11.90	13.30	.....	.....	.....
209	11.24	10.23	10.63	11.07	11.15	10.96	11.20	11.23	11.58	12.58	12.99	13.51	14.52	.....
Average for Holsteins	11.31	10.64	10.84	11.10	11.27	11.15	11.31	11.40	11.51	12.20	12.83	13.01	13.78	13.42
300	13.07	12.27	12.14	11.81	11.66	11.35	11.38	12.15	12.56	13.85	.....	.....	.....	.....
301	13.20	12.50	12.57	12.64	13.09	12.86	12.63	12.64	12.49	11.78	13.55	13.04	13.27	.....
Average for Ayrshires	13.14	12.39	12.36	12.23	12.38	12.11	12.01	12.40	12.53	12.82	13.55	13.04	13.27	.....
400	13.71	13.29	13.05	12.48	13.06	13.05	12.96	13.08	13.03	12.43	12.84	.....	.....	.....
402	13.74	13.29	13.07	13.07	13.16	12.97	13.02	12.93	13.31	13.94	.....	.....	.....	.....
403	12.85	12.16	11.75	11.56	11.56	11.65	12.77	12.52	12.38	12.90	13.19	.....	.....	.....
Average for Shorthorns	13.43	12.91	12.62	12.37	12.59	12.56	12.92	12.84	13.07	13.09	13.02	.....	.....	.....
Grand total average	12.74	12.26	12.29	12.24	12.35	12.50	12.61	12.70	12.78	13.16	13.46	14.04	14.23	15.29

Table 20 shows the average per cent of the total solids found as protein, casein, albumin, fat, and sugar, and the effect of the stage of lactation on this relation. The per cent of the total solids as ash is given for the general average only. On the average the total protein represents 27 per cent of the total solids, and at the end of the lactation period constitutes about 3 per cent more than at the beginning.

The casein increases slightly more than the total protein in per cent of the total solids. On the average this constituent makes up 22.1 per cent of the total solids. The albumin averages 2.3 per cent of the total solids and shows a decline in relation to the total solids at the end of the lactation period.

The fat represents 31.3 per cent of the total solids and shows a small variation during the lactation period in the way of an increase of about 2 per cent of the total solids near the end of the lactation period.

The sugar represents 37 per cent of the total solids on the average. The ratio is quite uniform until about the ninth month, when a decline begins which continues until the end of the lactation period. In the beginning the sugar constitutes 38.2 per cent of the total solids, and in the fourteenth period 32.8 per cent. The sugar, as already shown, remains practically constant until near the end of the milking period, when it declines somewhat. At the same time the other solids increase rapidly. As a result the ratio of the sugar to total nitrogen drops to a marked degree.

The ash, which shows practically no variation in amount during the lactation period, represents on the average 5.3 per cent of the total solids.

TABLE 20.—*Average per cent of total solids in the milk, and percentage as protein, casein, albumin, fat, sugar, and ash, by 4-week periods.*

Period No.	Total solids.	Water.	Per cent of solids as—					
			Protein.	Casein.	Albumin.	Fat.	Sugar.	Ash.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
1	12.74	87.26	25.5	21.0	2.35	31.4	38.2	....
2	12.26	87.74	24.9	19.2	2.34	31.4	39.5	....
3	12.29	87.71	24.9	20.3	2.07	30.8	40.2	....
4	12.24	87.76	25.6	20.3	2.08	30.8	39.4	....
5	12.35	87.65	26.3	21.2	2.12	30.9	38.9	....
6	12.50	87.50	26.0	21.4	2.14	30.3	38.0	....
7	12.61	87.39	26.3	21.3	2.17	30.4	38.7	....
8	12.70	87.30	26.1	21.6	2.11	30.3	38.0	....
9	12.78	87.22	27.9	22.5	2.20	31.1	36.2	....
10	13.16	86.84	29.1	23.2	2.33	31.2	34.6	....
11	13.46	86.55	28.9	23.7	2.47	31.4	35.2	....
12	14.04	85.96	29.0	24.1	2.54	32.3	35.0	....
13	14.23	85.70	30.4	25.6	2.06	32.8	33.0	....
14	15.29	84.71	26.7	24.2	1.88	33.2	32.8	....
Average	13.05	86.95	27.0	22.1	2.20	31.3	37.0	5.3

RELATIVE SIZE OF FAT GLOBULES.

Table 21 gives the relative size of the fat globules for each cow, and figure 13 shows the average for the 11 cows expressed graphically.

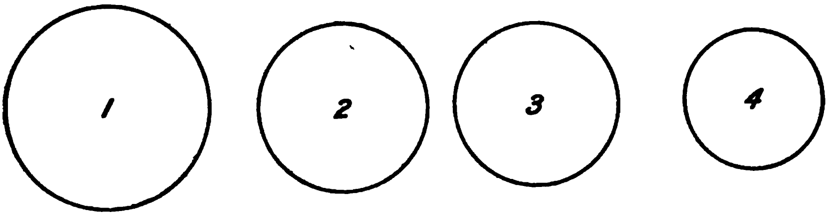

FIG. 13.—Relative size of fat globules as influenced by stage of lactation. (1) First 4-week period; (2) fifth 4-week period; (3) ninth 4-week period; (4) thirteenth 4-week period.

A determination such as this necessarily lacks the exactness of a determination like that for fat or nitrogen. However, 3 tubes were prepared from each sample and 3 readings taken from each tube according to the method given. An average of these 9 distinct counts for each sample reduces the variation to a minimum, and the further average of 4 separate samples, as given in the table, should give consistent results. It may be observed that the fat globules are especially large shortly after the beginning of the lactation period.

An examination of the weekly analyses in the Appendix will make the extent of the variation in size of fat globules clearer. It will be seen that in every case the cows began their lactation period with fat globules in relative size about twice the average for the milking period. The relative size declines sharply during the first six weeks, remains fairly constant for five or six months, after which the decline is much more rapid to the end of the lactation period.

It should be borne in mind that the relative size represents comparative volume and not diameter. To represent the comparative diameters of the globules it is necessary to extract the cube root of the figures representing the relative size.

In figure 13 the circles represent the comparative diameter of the average fat globules as found for the 11 cows during the first, fifth, ninth, and thirteenth 4-week periods.

TABLE 21.—*Relative size of fat globules in milk of each cow, and breed average, by 4-week periods.*

Cow No.	First period.	Second period.	Third period.	Fourth period.	Fifth period.	Sixth period.	Seventh period.	Eighth period.	Ninth period.	Tenth period.	Eleventh period.	Twelfth period.	Thirteenth period.	Fourteenth period.
4	363	423	370	229	267	235	290	318	228	167	....	....	....	....
99	556	339	325	274	264	349	370	367	270	209	263	315	....	....
118	....	1,280	417	879	358	373	301	334	335	259	342	229	....	....
Average for Jerseys	460	681	371	461	296	319	323	340	278	212	308	272	....	....
205	242	147	148	147	127	82	107	96	98	90	81	117	102	....
206	253	269	124	157	134	155	132	110	96	74	79	....	....	....
209	321	139	136	138	104	89	98	99	105	79	63	76	118	....
Average for Holsteins	272	185	136	147	122	109	112	102	100	81	74	97	110	....
300	235	163	148	135	115	133	93	80	75	129	....	....	....	....
301	232	189	142	155	165	178	163	151	146	114	146	93	110	....
Average for Ayrshires	234	176	145	145	140	156	128	116	111	122	146	93	110	....
400	442	593	317	245	250	277	231	197	214	179	194	....	....	....
402	566	561	394	274	280	232	271	214	213	193	....	....	....	....
403	357	303	213	183	134	141	146	147	203	175	128	....	....	....
Average for Shorthorns	455	486	308	234	221	217	216	186	210	182	161	....	....	....
Grand total average	357	401	249	256	200	204	201	192	180	152	118	166	110	....

It seems impossible to correlate the variation in relative size of the fat globules with the variation of any constituent of the milk. In the early part of the milking period a decline in the per cent of both fat and protein is accompanied by a decline in the size of the fat globules, while at the end of the lactation period the fat globules are the smallest and the fat and protein content are at the highest.

It might be reasonably expected that the relative size of the fat globules would bear some relation to the physical constants of the fat. Table 22 gives the average, by periods, of the relative size, melting point, iodin number, Reichert-Meissl number, and saponification number in order that such a comparison may be made.

The melting point rises as the relative size of the globules decreases. The change in the former, however, is not great, and a study of the weekly analyses shown in the table in the Appendix fails to indicate any special relation between these two characteristics in particular samples.

What is said of the relation of the relative size to the melting point may also be said of its relation to the iodin number. From the first period to the second the iodin drops with the size of the fat globules, but as the fat globules decline toward the end of the lactation period the iodin number goes strongly in the opposite direction.

The Reichert-Meissl number declines as the fat globules become smaller. The average results, as shown in Table 22 and in figure 14, seem to indicate a correlation between the size of the fat globules and the Reichert-Meissl number. An examination of the weekly samples from the table in the Appendix seems to bear out this statement.

TABLE 22.—*Relation of size of fat globules to physical constants of the fat.—Average determinations by 4-week periods.*

Period No.	Relative size.	Melting point.	Iodin number.	Reichert-Meissl number.	Saponification number.
		°C.			
1	357	31.73	33.28	29.13	233.7
2	307	32.96	31.58	27.49	230.4
3	249	32.82	32.22	27.06	231.0
4	256	33.08	30.85	26.45	229.6
5	200	33.28	31.36	26.58	229.2
6	204	33.25	31.72	26.40	228.9
7	201	33.32	32.96	25.52	225.7
8	192	33.41	33.26	25.20	226.7
9	180	33.51	34.56	24.23	225.6
10	152	33.94	35.41	22.48	223.4
11	162	34.67	35.46	22.24	223.8
12	166	33.85	35.17	20.29	220.6
13	110	36.48	39.22	17.20	216.6

MELTING POINT.

Table 23 gives details regarding the melting point of the fat for each animal. The same data are shown graphically in figure 14. With the exception of the last end of the lactation period, there was but little change in the melting point. The table in the Appendix gives the details of this determination by weeks. An examination of the table will show more clearly the variation that occurs at the beginning and end of the lactation period. There seems to be no uniformity in regard to the changes that are found in the melting point during the first few weeks of the lactation period. With three of the animals—namely, Nos. 301, 118, and 99—there is a decided increase in the melting point from the first to the third week. With Nos. 205, 206, 300, and 400 there is a decided decline for the same period, while the remaining 4 show practically no change. The averages of all the cows by 4-week periods show an increase from the first to the second period. These variations in the melting point at this time can not be attributed to the feed, since that was uniform. It is probable that the explanation lies in the extent to which fat was taken from the animal's body to supply that produced in the milk.

It has been found in other investigations not as yet reported that when an animal on account of insufficient feed declines rapidly in weight due to fat being removed from the body to support milk production, the melting point of this fat is raised, indicating that it has some of the characteristics of body fat. We also find that the fat produced during the first few days of the lactation period, during the stage before the milk is ordinarily used for food, always has an unusually high melting point. It is also possible that these variations in the melting point during the first week are influenced by the length of interval that elapsed before beginning the sample. The date of beginning the samples was governed by the condition of the cow, the plan being to begin as soon as the milk was deemed suitable for food purposes. In some cases the time that elapsed before the sampling was begun was only 5 days and in others as high as 10 days.

After the first 3 weeks very little change is noted in the melting point until that point in the lactation period is reached when the milk flow declines very rapidly and when all the constituents show a decided tendency to change. This occurred at about 2 months before the end of the lactation period. In several cases the melting point rose as much as 6° during the last 5 weeks, the most extreme figure being that for cow No. 205, where the melting point reached 52.9° C., while the average figure for the same cow was about 33° C.

It is impossible to say what changes take place in the composition of the fat that result in this rapid rise in the melting point near the end of the lactation period. It is accompanied by a high iodin number and an especially low Reichert-Meissl number. An examination in detail of the weekly analyses in the Appendix indicates that in most cases, for example, with cow No. 205, an extremely high melting point is associated with an unusually low Reichert-Meissl and saponification number and a correspondingly high iodin number. This indicates that the decline in volatile acids, which have a very low melting point compared with the other fats, far more than offsets the increase in olein indicated by a high iodin number, which would tend to lower the melting point. On the whole, the melting point seems to be little affected by the period of lactation when the feed is kept uniform, except at the extreme end, when abnormally high results may be expected.

Table 23.—*Average melting point of the fat for each cow, and breed average, by 4-week periods.*

Cow No.	First period.	Second period.	Third period.	Fourth period.	Fifth period.	Sixth period.	Seventh period.	Eighth period.	Ninth period.	Tenth period.	Eleventh period.	Twelfth period.	Thirteenth period.	Fourteenth period.
	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.
4	32.36	32.63	33.39	33.25	33.30	33.44	32.94	33.24	33.03	32.97	.....	.....	.....	.....
99	24.94	33.24	33.36	34.53	33.78	34.08	34.07	34.33	34.64	33.81	34.88	34.35	.....	.....
118	26.62	32.66	33.31	33.31	33.80	33.40	33.92	33.66	33.39	33.59	33.81	33.68	33.46	33.50
Average for Jerseys	27.97	32.84	33.35	33.70	33.63	33.64	33.64	33.74	33.69	33.46	34.35	34.02	33.46	33.50
205	33.41	32.67	33.39	33.76	33.02	32.93	32.88	32.98	33.26	33.09	33.01	32.54	41.80	48.34
206	32.95	33.52	31.94	32.06	32.47	32.47	32.64	33.13	32.81	32.92	38.80	.....	.....	.....
209	32.58	32.16	32.06	31.84	33.04	31.69	32.30	32.78	32.85	33.82	33.15	35.45	37.39	.....
Average for Holsteins	32.98	32.78	32.46	32.55	32.84	32.36	32.61	32.96	32.97	33.28	34.99	34.00	39.60	48.34
300	34.80	33.39	33.45	33.54	33.74	33.87	33.83	33.30	33.30	34.04	.....	.....	.....	.....
301	32.07	33.21	32.61	32.80	33.85	32.98	33.98	33.55	33.33	33.10	34.35	33.23	33.28	.....
Average for Ayrshires	33.44	33.30	33.03	32.17	33.80	33.43	33.91	33.43	33.32	33.57	34.35	33.23	33.28	.....
400	33.91	32.99	31.61	33.15	33.01	33.88	33.63	34.13	34.21	36.40	36.49	.....	.....	.....
402	32.69	32.79	33.20	33.09	32.95	33.99	33.76	33.79	34.65	36.31	.....	.....	.....	.....
403	32.70	33.32	32.70	32.60	33.15	32.98	32.54	32.65	33.14	33.28	32.92	.....	.....	.....
Average for Shorthorns	33.10	33.03	32.50	32.95	33.04	33.62	33.31	33.52	34.00	35.33	34.71	.....	.....	.....
Grand total average	31.73	32.96	32.82	33.08	33.28	33.25	33.32	33.41	33.51	33.94	34.68	33.85	36.48	.....

REFRACTIVE INDEX.

The refractive index of the fat was determined as mentioned with the Zeiss-Abbe refractometer under standard conditions. This determination was continued through the entire lactation period of 5 of the animals, and a number of determinations were made from samples representing the milk of the others. The results show a decided uniformity under all conditions. The determinations were finally dropped, since the variations found, due to the stage of lactation, were too small to be of any importance. The only variation that the data show at all is a slightly higher index in most cases during the first 2 or 3 weeks of the lactation period than was found during the remainder. We found no tendency for the refractive index to change during the last few weeks of the lactation period, as was found to be true of nearly every constituent of the milk, and also all the physical constants of the fat.

REICHERT-MEISSL NUMBER.

The Reichert-Meissl number, or the volatile acid determination, is considered one of the most important of the physical constants in connection with butterfat. The results of this determination by 4-week periods are found in Table 24 and are shown graphically in figure 14. In general there is quite a uniform decline from the beginning of the lactation period to the end, although this fluctuates with individual animals, as will be seen by inspecting the figures in detail. By eliminating these variations there is a marked decline with the advance in period of lactation.

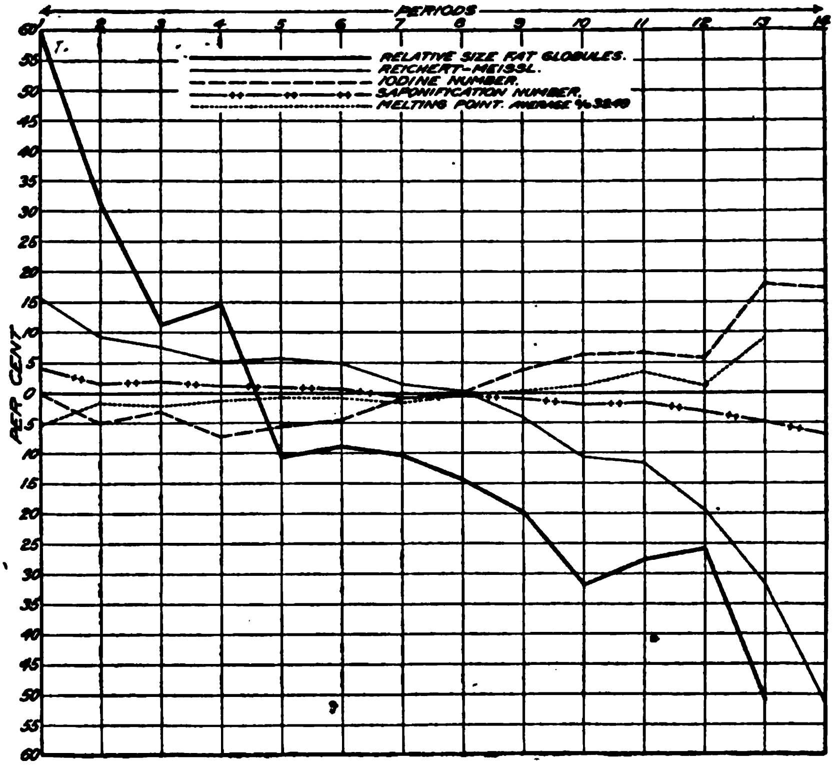

FIG. 14.—Variations in fat characters at end of each 4-week period.

The total number of determinations made was 484; the lowest was 6.10 and the highest 33.38. The statement below shows the distribution of these determinations from the lowest to the highest and the per cent of the whole number that come within limits of 5.

	Per cent.
Between 5 and 10	0.8
10 and 15	2.2
15 and 20	4.5
20 and 25	33.9
25 and 30	50.2
30 and 35	8.2

Fifty per cent of the total number come between 25 and 30, while 7.5 per cent of the total number come below 20. Richmond considers butter with a Reichert-Meissl number less than 25 suspicious, and suggests that this number be adopted as the commercial limit. He also says that the absolute lowest limit must be fixed at 20. The statement given shows that 41.4 per cent of the determinations made were 25 or less, while 7.5 per cent went below the absolute limit as suggested by Richmond.[1]

The low figures here given are accounted for to a large extent by the fact that the cows were fed entirely on dry feed, while under commercial conditions fully two-thirds of the butter on the market is produced from animals that are consuming green feed, which is assumed to give a higher Reichert-Meissl number. The further explanation of the large number of low determinations is the fact that each sample represents an individual cow, and toward the end of the lactation period when these abnormal samples occur the production of milk and fat is low. As a rule butter that comes on the market is a mixture of fat from several animals, and only under exceptional conditions would it happen that all were at such a stage of lactation as to give such an abnormally low Reichert-Meissl number. However, it is entirely possible that such figures might be found where samples of butter come from small lots made from a limited number of cows, and this possibility should be taken into account.

The change in this constant, as is true with that of most of the others, is much more pronounced near the close of the lactation period, when the decline in milk production is rapid. As is the case with the melting point, variations in the Reichert-Meissl number during the first 5 or 6 weeks of the lactation period is irregular. In some cases there is a marked increase and in others a great decrease. The cause of this is probably to be explained in the same manner as was mentioned in connection with the similar variations of the melting point—that is, on account of the difference in the length of time represented from the date of calving and the probability that in some cases the animal was drawing on the reserve fat of the body and using it in forming milk fat, while in other cases this was not done.

The Reichert-Meissl number is more affected by the stage of lactation than any other of the physical constants with the exception of the relative size of the fat globules. The marked similarity between the curve representing these two will at once attract attention.

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[1] Richmond, Henry Droop. Dairy chemistry. London, 1899. See p. 262.

TABLE 24.—*Average Reichert-Meissl number for each cow, and breed average, by 4-week periods.*

Cow No.	First period.	Second period.	Third period.	Fourth period.	Fifth period.	Sixth period.	Seventh period.	Eighth period.	Ninth period.	Tenth period.	Eleventh period.	Twelfth period.	Thirteenth period.	Fourteenth period.
4	29. 22	28. 72	28. 52	28. 50	28. 96	29. 20	26. 87	28. 63	25. 24	25. 95	.....	.....	.....	.....
99	30. 16	28. 88	32. 09	30. 95	27. 67	31. 21	27. 03	27. 34	27. 03	25. 83	24. 73	18. 43	.....	.....
118	29. 54	23. 28	24. 14	23. 69	23. 90	24. 64	26. 66	23. 12	25. 04	22. 85	22. 79	20. 22	14. 23	14. 21
Average for Jerseys	29. 64	26. 96	28. 25	27. 71	26. 84	28. 35	26. 85	26. 36	25. 77	24. 88	23. 76	19. 33	14. 23	14. 21
205	26. 66	26. 01	26. 33	27. 38	27. 82	26. 92	28. 05	27. 53	27. 86	26. 06	25. 63	20. 39	12. 77	10. 27
206	30. 15	29. 48	28. 15	24. 58	27. 19	24. 51	24. 28	23. 39	23. 53	20. 76	17. 62	.....	.....	.....
209	25. 65	26. 84	25. 10	27. 05	24. 82	24. 68	22. 79	23. 47	24. 23	20. 17	21. 32	20. 70	21. 14	.....
Average for Holsteins	27. 49	27. 44	26. 53	26. 34	26. 61	25. 37	25. 04	24. 80	25. 21	22. 33	21. 52	20. 55	16. 96	10. 27
300	27. 66	28. 96	27. 76	25. 76	26. 83	25. 76	24. 57	23. 87	23. 09	17. 96	.....	.....	.....	.....
301	30. 59	27. 09	26. 58	25. 13	24. 88	26. 79	25. 59	26. 40	24. 42	24. 36	18. 09	21. 72	20. 67	.....
Average for Ayrshires	29. 13	28. 03	27. 17	25. 45	25. 86	26. 28	25. 08	25. 14	23. 76	21. 16	18. 09	21. 72	20. 67	.....
400	30. 77	29. 31	25. 95	25. 99	28. 58	26. 54	24. 70	25. 99	24. 46	22. 57	22. 25	.....	.....	.....
402	30. 72	27. 14	26. 09	25. 60	26. 07	24. 12	23. 75	22. 93	18. 39	16. 61	.....	.....	.....	.....
403	29. 36	26. 67	26. 31	26. 30	25. 69	26. 02	26. 38	24. 53	23. 27	24. 25	25. 02	.....	.....	.....
Average for Shorthorns	30. 28	27. 71	26. 32	25. 96	26. 78	25. 56	24. 94	24. 48	22. 04	21. 14	23. 64	.....	.....	.....
Grand total average	29. 13	27. 49	27. 06	26. 45	26. 58	26. 40	25. 52	25. 20	24. 23	22. 48	22. 18	20. 29	17. 20	.....

IODIN NUMBER.

The iodin number, or Hübl number, was determined according to the official method. The results of this determination by 4-week periods are shown in Table 25. The average results for 11 cows are illustrated in figure 14. The total number of determinations made was 473, the lowest being 23.8 and the highest 49.4. The statement below shows how these determinations are distributed between the minimum and maximum variations. It will be seen that 47.4 per cent of the whole lie between 30 and 35, and 93.8 per cent of all range between 25 and 40.

	Per cent.
Between 20 and 25	0. 4
25 and 30	21. 5
30 and 35	47. 4
35 and 40	24. 9
40 and 45	5. 4
45 and 50	0. 4

With the beginning of the lactation period we find the same irregular results as mentioned in connection with the Reichert-Meissl number and the melting point. With 8 of the cows the iodin number declines from the first to the second month and in some cases the change is very striking. With 3 of the cows the change is the reverse from the first to the second month. The lowest point for the lactation period, according to the general average, is the fourth monthly period, after which there is a slight but gradual increase until to within 2 or 3 months of the end of the lactation period. The iodin number increases as a rule gradually until it reaches the highest point during the entire lactation period. Since the iodin number represents the olein, which is a soft fat with a low melting point, it would be assumed that an increase in this constituent of the fat would result in a decline in the melting point. The data given, however, show that in nearly every case the reverse is true. Even where the iodin number increases from an average of around 33 to 42 or 43, the melting point of the fat during the same period with some animals increased as much as 15°.

While there is no doubt that the tendency of the olein is to lower the melting point, its influence is counteracted by the stronger influence of the decline in the amount of butyrin. The melting point of butyrin is far below that of olein, and it therefore has a more marked effect upon the melting point. The amount of butyrin or butyric acid is indicated closely by the Reichert-Meissl number, and in all cases a high melting point is accompanied by a low Reichert-Meissl number, indicating that while a high olein usually goes with a high melting point the butyric acid is at the same time abnormally low. This results in a striking increase in the melting point, and these conditions are found mostly in the extremes of the lactation period, especially near the end.

TABLE 25.—*Average iodin number for each cow, and breed average, by 4-week periods.*

Cow No.	First Period.	Second period.	Third period.	Fourth period.	Fifth period.	Sixth period.	Seventh period.	Eighth period.	Ninth period.	Tenth period.	Eleventh period.	Twelfth period.	Thirteenth period.	Fourteenth period.
4	31.08	28.04	29.61	29.94	28.84	28.03	31.46	29.75	32.27	32.15	.....	.....	.....	.....
99	32.68	29.46	28.96	26.75	29.99	27.29	27.93	27.37	28.71	28.80	27.61	29.55	.....	.....
118	39.31	36.33	32.54	28.69	31.55	30.43	28.67	32.49	33.67	31.43	31.14	32.47	38.48	35.82
Average for Jerseys	34.36	31.28	30.37	28.46	30.13	28.58	29.35	29.87	31.55	30.79	29.38	31.01	38.48	35.82
205	37.12	34.54	33.23	31.85	31.77	32.64	32.62	33.45	34.07	35.55	35.40	37.53	42.57	42.24
206	31.00	30.57	35.53	31.70	31.79	31.67	33.14	34.25	33.91	35.27	36.53	.....	.....	.....
209	39.46	33.32	32.89	33.10	33.53	34.91	36.63	35.59	37.01	39.08	35.35	36.69	39.03	.....
Average for Holsteins	35.86	32.81	33.88	32.22	32.36	33.07	34.13	34.43	35.00	36.63	35.76	37.11	40.80	42.24
300	32.58	28.70	27.69	31.91	27.50	29.61	35.30	37.32	35.23	37.74	.....	.....	.....	.....
301	28.58	29.91	30.56	29.85	30.93	30.31	31.04	30.54	32.64	35.11	44.11	39.62	36.80	.....
Average for Ayrshires	30.58	29.31	29.13	30.88	29.22	29.96	33.17	33.93	33.94	36.43	44.11	39.62	36.80	.....
400	30.13	32.12	39.05	31.36	31.66	33.31	35.71	33.25	34.28	36.91	38.49	.....	.....	.....
402	30.76	29.21	31.15	30.42	32.08	35.16	35.13	35.47	41.01	42.19	.....	.....	.....	.....
403	33.33	35.18	33.19	33.75	35.28	35.57	34.96	36.34	37.32	35.24	35.21	.....	.....	.....
Average for Shorthorns	31.41	32.17	34.46	31.84	33.01	34.68	35.27	35.02	37.54	38.11	36.85	.....	.....	.....
Grand total average	33.28	31.58	32.22	30.85	31.36	31.72	32.96	33.26	34.56	35.41	35.48	35.17	39.22	39.08

SAPONIFICATION.

The saponification or Koettstorfer number was determined according to the regular official method. Table 26 gives the results of this determination by 4-week periods for each animal.

A total of 488 determinations of the saponification number were made, among which the lowest found was 200.1 and the highest 252.3. The figures below show the range of variation expressed in percentage. About 81 per cent of the total number come between 220 and 235.

	Per cent.
Between 200 and 210	1.6
210 and 215	2.2
215 and 220	6.9
220 and 225	20.4
225 and 230	34.2
230 and 235	26.0
235 and 240	4.8
240 and 245	1.8
245 and 250	1.4
250 and 255	0.2

The period of lactation seemed to exert a uniform effect upon the saponification value with all of the 11 cows. In general there was an almost uniform decline from the beginning to the end, with the exception that during the last 3 months the decline was most marked. This decline coincides closely with the decrease in the volatile acids as shown by the Reichert-Meissl number. Such a decline in the saponification number would be expected from the decline in the Reichert-Meissl number, since the low molecular weight of the volatile acids have the effect of holding up the saponification number, and when they are decreased a corresponding decline is expected. This decline is so consistent and so uniform that it may be safely assumed that it is a natural effect of the period of lactation and may be looked for to show most in the last end of the lactation period, unless there is some other factor to interfere. The ratio between the saponification number and the Reichert-Meissl number is constant throughout the lactation period, which indicates that it may be a readjustment of the proportions of the higher fatty acids.

TABLE 26.—*Average saponification number for each cow, and breed average, by 4-week periods.*

Cow No.	First period.	Second period.	Third period.	Fourth period.	Fifth period.	Sixth period.	Seventh period.	Eighth period.	Ninth period.	Tenth period.	Eleventh period.	Twelfth period.	Thirteenth period.	Fourteenth period.
4	231.1	233.1	232.9	229.1	230.7	229.0	227.8	229.4	234.4	235.9	.....	.....	.....	.....
99	230.6	232.1	229.5	232.3	227.7	231.7	227.3	239.8	234.3	231.4	229.4	219.1	.....	.....
118	228.5	224.7	229.6	229.0	230.2	226.6	229.4	224.8	225.1	227.6	237.0	223.9	219.5	219.1
Average for Jerseys	230.1	230.0	230.7	230.1	229.5	229.1	228.2	231.3	231.3	231.6	233.2	221.5	219.5	219.1
205	242.2	229.3	229.0	232.9	230.8	228.7	228.1	227.0	225.0	223.9	226.3	220.8	210.1	205.9
206	230.7	228.3	242.4	233.7	232.4	231.2	229.7	225.6	224.4	219.9	216.4	.....	.....	.....
209	237.2	230.6	231.6	230.8	228.3	229.0	224.0	222.4	222.0	219.2	222.0	220.3	215.3	.....
Average for Holsteins	236.7	229.4	234.3	232.5	230.5	229.6	227.3	225.0	223.8	221.0	221.6	220.6	212.7	.....
300	232.6	230.7	232.3	224.8	229.2	230.1	224.5	222.0	223.9	217.2	.....	.....	.....	.....
301	236.9	234.1	232.0	230.4	227.5	229.7	219.6	228.3	228.4	224.3	216.2	218.7	221.3	.....
Average for Ayrshires	234.8	232.4	232.2	227.6	228.4	229.9	222.1	225.2	226.2	220.8	216.2	218.7	221.3	.....
400	232.3	231.7	224.2	230.0	229.4	227.2	223.9	226.5	224.9	220.5	216.8	.....	.....	.....
402	234.3	233.9	229.8	223.0	228.3	224.3	223.7	222.7	215.8	211.5	.....	.....	.....	.....
403	234.3	225.4	228.1	229.9	226.4	230.1	224.6	225.1	223.8	226.4	226.2	.....	.....	.....
Average for Shorthorns	233.6	230.3	227.4	227.6	228.0	227.2	224.1	224.8	221.5	219.5	221.5	.....	.....	.....
Grand total average	233.7	230.4	231.0	229.6	229.2	228.9	225.7	226.7	225.6	223.4	223.8	220.6	216.6	.....

ASH.

Ash determinations were not made on the 7-day samples; they were prepared by combining 4 of these weekly composite samples. The total ash in this combined sample was determined according to the official method. The results may be seen in Tables 4 and 5.

The amount of ash was found to be fairly uniform in all samples except that near the end of the lactation period there was some increase, which seems to be the only change that can be attributed to the stage of the lactation period. Our analyses did not include a determination of the several mineral constituents, which is of equal if not of greater importance than finding the total ash present.

However, Dr. August Trunz,[1] at the University of Halle in 1903, conducted a very careful and complete investigation concerning these mineral constituents of milk as affected by the lactation period, and in order to make this bulletin more complete an abstract of his work is herewith incorporated. Full credit is given Dr. Trunz for this work, and for complete details reference should be made to his original article. Only that part of his work which has to do directly with the ash will be discussed, although in his original paper he includes a study of other constituents.

Dr. Trunz's investigation was conducted with two cows. Cow 655 was a cross between a Simmenthaler and a Norderditmarscher. She was 3½ years old at the beginning of the experiment, calved December 25, 1901, and went dry November 8, 1902. She was fed no regular ration, receiving the same feed as the rest of the herd which was changed 2 or 3 times during the period. The other cow, No. 674, was a pure Friesian. She was 7½ years old at the beginning of the experiment, calved January 14, 1902, and went dry December 6, of the same year. Since she was used for the production of baby milk her ration was kept uniform throughout the year. She received the following ration per 1,000 pounds live weight:

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[1] Trunz, August. Über die mineralischen Bestandteile der Kuhmilch und ihre Schwankungen im Verlaufe einer Laktationsperiode. Zeitschrift für Physiologische Chemie, vol. 40, No. 3/4, pp. 263–310. Strassburg, Dec. 5, 1903.

Lucern hay	pounds..	16
Barley straw	do....	8
Oats	do....	8
Linseed	do....	1
Wheat bran	do....	2

An analysis was made of the milk from each milking for 4 or 5 days after calving. After this, samples were taken at irregular intervals during the lactation period. Altogether 30 samples from each cow were analyzed. The total percentage of ash was determined as well as that of the various ash constituents, which included K^2O, Na_2O, CaO, MgO, SO_3, P_2O_5, Cl, and Fe_2O_3.

For the crude ash determination 40 to 50 grams of the milk were weighed into a platinum dish, evaporated to dryness, and then ignited at low redness until a perfectly white ash was obtained. The sample of ash for the determination of the individual constituents was obtained by evaporating about 1 liter of the milk in a nickel dish and igniting at low red heat. The soluble material, consisting largely of the alkaline chlorid, was extracted with hot water. The residue was then ignited at a somewhat higher temperature. Finally the two parts were united and evaporated to dryness in a platinum dish and then cautiously ignited and weighed. The ash secured in this manner was preserved in corked bottles until analyzed.

For the determination of the individual constituents 2.5 grams of the crude ash was weighed out, acidified with hydrochloric or nitric acid, and made up to 250 c. c. Then 50 or 100 c. c. of the filtered solution, corresponding to 0.5 or 1 gram of ash, was taken for analysis. The hydrochloric acid solution was neutralized with ammonia, treated with ammonium acetate, warmed, the iron phosphate filtered off, ignited and weighed. Half of this was considered to be ferric oxid.

From the filtrate, the calcium was precipitated as calcium oxalate and weighed as the carbonate and also as calcium oxid after igniting in the blast. The magnesium was precipitated from the concentrated filtrate as magnesium ammonium phosphate, and after ignition weighed as magnesium prophosphate.

In another 100 c. c. of the solution the sulphuric acid was precipitated as barium sulphate and the combined alkalies were determined in the filtrate as chlorids. The potassium was then determined by precipitation as potassium platinic chlorid and this calculated to potassium chlorid, subtracted from the combined chlorids to give the percentage of sodium chlorid.

The phosphoric acid was determined by the molybdate method and the chlorin by titration against deci-normal silver nitrate solution.

The author distinguishes between crude and pure ash, the former being what is usually considered as milk ash and the latter obtained by subtracting from the crude ash the mineral constituents combined with the proteids.

INDIVIDUAL COMPONENTS OF THE ASH.

Sodium and potassium.—Sodium and potassium underwent great variations in the course of the lactation period. In the colostrum period the percentage of potassium was lower than in the remainder of the lactation period, the first milking containing 16.15 and 17.98 per cent of K_2O in the total ash, which rose to 26.87 and 26.94 per cent at the time of the greatest secretion. It then fell slowly till the last two months, then rapidly to 16.89 per cent and 13.92 per cent at the end.

Excluding two figures which are abnormally high, the percentages of Na_2O show variations from 3.24 per cent to 8.5 per cent of the total ash for one cow and from 4.32 per cent to 8.56 per cent for the other. The tendency is for it to decline during the first half of the period and then rise during the second half.

Calcium oxid.—Excluding two abnormal figures, the calcium oxid varied between 23.88 per cent and 27.49 per cent for one cow and between 21.23 per cent and 25.78 per cent for the other, being somewhat higher in the colostrum. The variations were erratic and showed but slight change during the period.

Magnesium oxid.—The magnesium oxid varied from 4.52 per cent to 2.54 per cent and from 5.27 per cent to 2.51 per cent, falling during the first third and rising from then on to the end of the milking period. It was highest in the first milking of the colostrum.

Chlorin.—The chlorin in the case of one cow remained nearly constant during the entire period, being from 11.5 per cent to 12 per cent. In the case of the other it rose from 11.86 per cent to 24.77 per cent. The chlorin content of the crude ash and of the pure ash seemed to vary somewhat in their relation to each other.

Phosphoric acid.—In the case of the two cows, the crude ash of the colostrum period contained 26.60 to 31.46 per cent and 28.28 to 31.45 per cent phsphoric acid, respectively. The pure ash contained a somewhat smaller percentage, 24.02 to 26.97 per cent and 22.25 to 28.36 per cent, respectively.

With one cow there seemed to be irregular fluctuations which occurred at about the time of the changes in the food. The cow on the constant ration showed a gradual decline from an average of 30.36 per cent in the colostrum period to 25.58 per cent in the last 4 months, the last month showing a P_2O_5 content of 22.23 per cent.

Iron and sulphuric acid.—Iron and sulphuric acid were determined only to complete the analyses. They occur only in small amounts and do not undergo any considerable variation during the lactation period. Iron makes about 0.25 per cent to 0.5 per cent of the ash, and SO_3 about 1.5 to 2.5 per cent.

The author makes a distinction between the total nitrogen-containing substance and the total proteids, as will be noted in his tables. He determined the former by the ordinary Kjeldahl method and the latter by precipitation from the 10-times diluted milk by the addition of 15 to 20 c. c. of a solution made up of 190 c. c. 95 per cent alcohol, 8 grams 25 per cent acetic acid, and 4 grams tannic acid.

ADDITIONAL DATA FROM FIVE JERSEY COWS.

In addition to the data from the 11 animals used primarily for this investigation, we are able to make use of less complete data from 5 Jersey cows kept under somewhat different conditions. These 5 cows, which were registered Jerseys, are designated as Nos. 4, 43, 63, 62, and 27. The conditions under which these animals were kept differed from the 11 animals supplying the other data in three particulars, as follows: (1) They were not kept on a uniform ration throughout the milking period; (2) they were maintained at uniform weight; (3) they were kept farrow. On the other hand, the 11 animals used especially in this investigation were fed on a ration of uniform composition throughout the lactation period; no attempt was made to keep the weight uniform, and they were not kept farrow. The 11 cows were kept under what would be considered ordinary commercial conditions with the exception of uniformity in the ration. The 5 Jersey cows all received the same grain mixture, which remained unchanged throughout the entire year. During the greater part of the year they were fed corn silage and alfalfa hay, while for some 3 months during the summer season the corn silage was replaced by green alfalfa and green corn.

Composite samples of milk from the 5 Jersey cows were prepared by taking a definite number of cubic centimeters of milk per pound from each. These composite samples covered periods of 1 month each for Nos. 63, 43, and 4 and 10 days each for Nos. 62 and 27. Tables 27 and 28 give the analyses of these samples and the average weight of the animal for the periods represented.

TABLE 27.—*Data for 5 additional Jersey cows.—Determinations for 3 cows from composite samples taken at 30-day periods.*

COW NO. 63.

Thirty days, ending—	Milk.	Fat.	Nitrogen.	Sugar.	Ash.	Average weight.
	Pounds.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Pounds.*
Oct. 25	[1] 500.2	5.90	0.69	4.70	0.778	960
Nov. 24	641.4	6.22	.72	3.83	.780	940
Dec. 24	579.0	6.50	.69	....	.741	941
Jan. 23	563.3	6.40	.67	4.08	.740	945
Feb. 22	523.6	6.43	.70	4.35	.741	938
Mar. 23	520.9	6.35	.70	4.60	.771	941
Apr. 22	590.0	6.60	.70	5.05	.795	952
May 22	463.3	6.28	.68	4.50	.744	922
June 21	470.6	5.77	.65	4.40	.713	939
July 21	419.9	5.57	.68	4.10	.707	959
Aug. 20	420.1	5.20	.66	4.53	.684	955
Sept. 19	323.0	5.40	.69	3.66	.703	974
Oct. 2	[2] 118.6	5.56	.67	4.28	.696	963

COW NO. 43.

Oct. 25	[3] 920.5	4.60	0.57	5.30	0.710	825
Nov. 24	776.4	5.18	.59	5.45	.770	799
Dec. 24	680.0	5.42	.55	4.50	.747	811
Jan. 23	674.8	5.15	.52	4.55	.615	811
Feb. 22	652.5	5.35	.56	3.70	.707	803
Mar. 23	669.5	5.02	.55	4.10	.712	794
Apr. 22	634.9	5.20	.55	4.35	.720	803
May 22	615.6	5.03	.53	4.60	.728	784
June 21	586.8	4.80	.56	4.00	.697	792
July 21	619.0	4.20	.55	4.78	.664	812
Aug. 20	599.7	4.20	.57	4.49	.697	812
Sept. 23	[4] 509.8	4.30	.59	3.89	.609	835

COW NO. 4.

Nov. 24	[5] 1,266.4	5.18	0.63	4.97	0.842	801
Dec. 24	631.5	5.67	.64	3.83	.768	817
Jan. 23	643.6	5.80	.62	....	.800	814
Feb. 22	623.2	5.95	.62	4.00	.760	813
Mar. 23	622.4	5.97	.65	4.20	.791	814
Apr. 22	524.3	6.10	.63	4.70	.793	807
May 22	454.3	5.72	.66	4.60	.702	806
June 21	454.7	5.40	.67	4.10	.661	823
July 21	489.9	5.17	.64	4.41	.737	851
Aug. 20	475.5	4.67	.65	4.36	.684	837
Sept. 19	426.1	5.00	.68	4.16	.732	854
Oct. 5	[6] 161.7	5.20	.70	4.36	.731	861

[1] 22 days. [2] 13 days. [3] 32 days. [4] 34 days. [5] 48 days. [6] 16 days.

TABLE 28.—*Data for 5 additional Jersey cows—Determinations for 2 cows from composite samples taken at 10-day periods.*

COW NO. 62.

Ten days ending—	Milk.	Fat.	Nitrogen.	Sugar.	Ash.	Average weight.
	Pounds.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Pounds.*
Oct. 15	115.9	5.14	0.63	5.08	0.763	888
Oct. 25	139.6	5.80	.63	4.85	.764	883
Nov. 4	147.3	5.20	.63	5.30	.761	882
Nov. 14	156.4	5.00	.62	....	.770	882
Nov. 24	150.2	5.30	.62	6.48	.765	884
Dec. 4	137.5	5.10	.63	....	.750	882
Dec. 14	135.2	5.60	.63	3.93	.761	880
Dec. 24	138.4	5.55	.63	4.61	.702	894
Jan. 3	134.9	5.10	.65	4.55	.768	895
Jan. 13	123.2	5.20	.62	5.00	.700	886
Jan. 23	119.4	5.60	.62	4.23	.750	894
Feb. 2	114.5	5.40	.63	4.43	.757	898
Feb. 12	112.0	5.55	.62	3.93	.754	904
Feb. 22	104.7	5.45	.65	3.52	.759	903
Mar. 3	104.8	5.30	.66	6.18	.700	912
Mar. 13	103.8	5.30	.65	4.48	.712	906
Mar. 23	98.8	5.20	.63	3.88	.735	909
Apr. 2	96.5	5.50	.64	4.85	.778	907
Apr. 12	87.9	5.10	.66	4.51	.785	919
Apr. 22	90.9	5.40	.60	4.30	.720	913
May 2	84.4	4.95	.58	5.00	.657	910
May 12	77.6	5.45	.64	4.70	.837	910
May 22	72.6	5.30	.61	4.40	.800	919
June 1	79.3	5.50	.60	3.50	.916	925
June 11	73.0	5.30	.62	4.50	.723	924
June 21	68.0	5.20	.64	4.20	.732	923
July 1	65.5	5.30	.63	4.40	.655	931
July 11	64.6	5.20	.60	4.61	.713	929
July 21	56.2	5.20	.59	4.58	.686	911
July 31	49.2	5.10	.58	4.55	.688	897
Aug. 10	45.6	5.00	.60	4.50	.690	884
Aug. 20	41.0	5.10	.60	4.25	.689	905

COW NO. 27.

Oct. 15	[1] 181.3	4.20	0.52	5.00	0.745	924
Oct. 25	292.6	6.20	.52	4.70	.744	857
Nov. 4	310.4	5.60	.52	5.30	.745	846
Nov. 14	325.5	5.25	.55	5.00	.723	861
Nov. 24	314.3	5.30	.56	....	.736	890
Dec. 4	289.2	5.10	.58	3.76	.730	879
Dec. 14	287.6	5.60	.59	4.40	.764	872
Dec. 24	283.0	5.40	.58	4.86	.698	861
Jan. 3	272.3	5.10	.61	5.03	.762	873
Jan. 13	274.9	5.60	.62	5.30	.691	865
Jan. 23	266.7	5.10	.64	4.30	.721	882
Feb. 2	240.5	5.60	.62	4.98	.677	865
Feb. 12	243.1	5.80	.64	4.83	.750	875
Feb. 22	234.6	5.75	.64	4.35	.727	872
Mar. 3	245.6	5.60	.66	5.08	.776	885
Mar. 13	243.9	5.75	.65	4.66	.812	883
Mar. 23	244.2	5.70	.65	3.90	.775	897
Apr. 2	235.0	5.70	.67	5.30	.771	888
Apr. 12	231.6	5.60	.68	4.96	.789	900
Apr. 22	242.3	5.60	.66	4.60	.787	902
May 2	243.9	5.50	.67	4.90	.737	899
May 12	236.6	5.55	.68	4.50	.758	902
May 22	218.4	5.50	.66	4.50	.754	914
June 1	222.2	5.70	.65	....	.852	924
June 11	204.0	5.90	.62	4.70	.841	925
June 21	191.1	5.70	.64	4.50	.767	929
July 1	173.8	5.70	.61	4.67	.711	926
July 11	194.3	5.50	.68	4.69	.660	932
July 21	189.3	5.40	.63	4.80	.704	899
July 31	182.8	5.40	.63	4.08	.655	901
Aug. 10	183.5	5.00	.65	4.50	.672	906
Aug. 20	182.2	5.30	.67	4.93	.646	928
Aug. 30	173.7	5.70	.62	4.58	.597	935
Sept. 9	184.9	5.60	.67	4.93	.660	938
Sept. 19	161.6	5.60	.71	3.79	.705	938
Sept. 29	162.6	5.80	.70	4.33	.703	937
Oct. 9	149.4	6.00	.69	4.35	.689	958

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[1] Only 6 days.

EFFECTS OF MAINTAINING THE ANIMALS AT UNIFORM WEIGHT.

This group of 5 cows was kept, as stated, as near as possible at uniform weight. Each animal was weighed at a stated hour each day, and the ration increased or diminished in quantity as might seem necessary in order to keep it at a stationary weight. However, it is impossible with a heavy milking cow to prevent the weight from declining during the first few weeks of the lactation period. It will be noticed that in the case of No. 27 there was a considerable decline at this time and a smaller decline with Nos. 43 and 63. This decline in weight, which indicates a drawing on the reserve material in the body for milk production, may be reasonably expected to exert considerable effect upon the composition and properties of the milk, and this has been found to be the case. Some results of it are noticeable in the tables presented.

POSSIBLE VARIATIONS DUE TO THE RATION.

While the ration given these animals was not exactly the same throughout the lactation period and varied to a small extent as between the individuals, it is not believed that this variation was of sufficient extent to bring about any large change in the composition of the milk produced.

EFFECT OF KEEPING THE COWS FARROW.

Keeping the cows farrow might be expected to account for considerable variation in results as compared with the 11 cows that were developing a fetus during the latter part of the lactation period. The tables show a marked uniformity in the composition of the milk throughout the lactation period with each of these animals. This is probably accounted for by the reasons given, and, furthermore, with the exception of No. 62 these cows were all still producing milk at the end of the 12 months included in the experiment. If the period covered by the investigation had continued until the cows ceased to produce milk, it is probable that there would have been more change in the composition of the milk. Still, with No. 62, where the data include the entire lactation period, there seems to be little change in the composition of the milk in the last periods. It is well understood that as a rule an animal that is farrow continues to produce milk for a longer time than one that is pregnant.

The smaller range of variation in the composition of the milk during the year for these 5 cows as compared with the 11 is due to the fact that they were farrow. The per cent of nitrogen remains practically stationary with all 5 of the animals with the exception that in the case of No. 27 it is low in the first few periods. The probable cause of this is discussed on page 42. The per cent of fat, like the nitrogen, does not show much variation during the lactation period, there being no noticeable increase even at the end of the 12 months. The per cent of sugar remains fairly constant, and agrees with the data of the 11 cows heretofore given in declining to some extent in the latter part of the lactation period. There is no noticeable change in the per cent of ash, unless it be a slight decline.

While the results as previously given for the 11 cows fairly represent the changes that take place during the lactation period under normal conditions, the data of the 5 animals here under consideration assist in pointing out what factors are responsible for the changes that take place during the normal lactation period.

GENERAL DISCUSSION OF THE RESULTS.

It is evident from the data presented that certain changes in the composition of milk may be expected under normal conditions to occur during the lactation period. The lactation period in regard to its effect upon the composition of milk may be divided roughly into three parts.

The first stage includes the interval from the time the secretion of milk begins until the composition reaches normal, and covers a period of from 3 to 6 weeks. After the birth of the calf the colostrum is first secreted, which contains, as is well known, an abnormally high per cent of protein and of ash. This extremely abnormal composition changes rapidly during the first 4 days. Milk is ordinarily considered to be fit for food about the fifth day, although the changes in the composition continue for some time. The per cent of total protein, as well as of fat, as a rule continues to decline for from 3 to 6 weeks. One prominent characteristic of the fat during this first stage is the extremely large globules which are found in the beginning of the period and which decline rapidly in size during the first few weeks. During this first stage the composition of the fat also shows an irregular variation from the normal. The iodin number is ordinarily higher than the average; likewise the Reichert-Meissl number and the saponification. As a rule the melting point is abnormally high during the first few days of the lactation period, but soon reaches normal.

The second stage in the lactation period begins when the composition of the milk becomes normal, and continues until a point is reached when a rapid decline in the quantity of milk produced begins. Ordinarily this occurs within about 6 weeks to 2 months from the end of the lactation period. The length of the second stage will depend upon the length of the time the cow produces milk, and to some extent upon the quantity. If the complete lactation period of the cow be

10 months, this second stage will cover under average conditions about 6½ months. During this interval the composition of the milk remains in general quite uniform. There is a slight increase in the latter part in the nitrogen and in the fat, but these are not marked. The sugar remains practically constant. The changes in the fat most noticeable are a gradual decline in the size of the fat globules, which is accompanied by a decline in the Reichert-Meissl number and in the saponification number.

The third stage in the lactation period in some cases has a rather definite line of division from the second stage; in others the change is gradual. It begins at that point when the decline in milk production becomes rapid on account of the end of the lactation period being close at hand, and ordinarily this change begins from 6 weeks to 2 months before the end of the lactation period. During this third stage the composition of the milk changes widely from the average for the entire period, and while the extent of these changes varies with different animals, they are uniform to the degree that they may be reasonably counted on to occur under all normal conditions. The per cent of total protein rises rapidly, followed by the fat, although on the average the protein makes slightly the larger increase. During this stage the total protein content may be one-third higher than that present during the middle of the lactation period. The casein and albumin remain in practically the same proportions. The fat undergoes marked variations at this time. The size of the fat globules becomes very small, the melting point rises to a marked degree, the iodin number increases, the Reichert-Meissl number becomes abnormally low, and the saponification number likewise shows a strong decline.

RELATION OF STAGE OF LACTATION TO USE OF MILK AS FOOD.

In carrying on the investigations herein reported no attempt was made to determine how long after parturition milk is fit for human food. It is evident from the wide variations caused by the lactation period, especially in the per cent of protein present, that it is of considerable importance in many cases to consider the stage of the lactation period of the animal furnishing the milk in connection with its use as food. For infant feeding especially the amount of protein present is one of the important questions, and since a variation of one-third may be expected in the protein due to the stage of lactation, this factor should be understood and taken into account in modifying milk for infant feeding. Where mixed milk of a herd is used wide variation due to this cause would naturally be less liable to occur, but where the source of supply is one animal or a limited number all in the same stage of lactation the importance of this factor as influencing the composition of the milk would be considerable.

RELATION TO CHURNING.

The plan for the investigation contemplated churning tests to be made at intervals in order to observe the effect of the stage of lactation upon the time required for churning. However, many difficulties were experienced in working out a method to be followed in dealing with cream from individual animals and a satisfactory method was not evolved until the investigation was too far advanced to yield results of sufficient importance to be given in detail. The partial results, however, corroborated the common observation that the milk of cows advanced in the period of lactation churns with difficulty. In fact, the cream from all the animals churned with more difficulty near the end of the lactation period, and with several the last few samples secured at the end of the lactation period could scarcely be churned at all. Samples from Nos. 205, 206, 209, and 118 were found which we were unable to churn after trying every method we could devise. Persistent and violent shaking of this cream in glass jars at temperatures ranging from 10° to 30° C. failed to show any sign of churning after several hours of such agitation where cream under ordinary conditions would churn in a few minutes. The cream was also mixed with water and reseparated with a centrifugal separator to reduce the amount of solids not fat, but the cream still refused to churn.

The methods ordinarily followed in getting the samples of fat for analysis had to be modified with these samples and the fat extracted with ether. All the samples that could not be churned were near the end of the lactation period. It was observed with these same animals that the cream churned more and more difficultly as the end of the lactation period approached until the stage was reached when it became impossible to churn the samples. The conditions bringing about this difficulty in churning will be made the object of further investigation, but from the data at hand it appears that it was associated with a high per cent of protein and small fat globules, and it is believed these two factors together are the main causes of the difficulties experienced.

ABNORMAL TASTE IN MILK AT END OF LACTATION PERIOD.

It was observed with cows 118, 99, 206, and 205 that near the end of the lactation period a strong abnormal taste and odor developed in the milk within 24 hours after it was drawn from the cow. The flavor present might be described as a rancid and bitter taste combined.

On June 17 samples of milk were taken from cows 209, 205, and 403. The former two were near the end of the milking period and the latter near the beginning. These samples were cooled at once to

10° C. and placed in an ice box that maintained the above temperature. Forty-eight hours later a slightly stale taste was observed in the milk of 209; that of 205 showed an extremely bad condition, a rancid, bitter taste strongly developed; the milk of 403 showed no abnormal taste. After 6 days the sample from 403 showed a slight acid coagulation and the mixed samples of 205 and 209 showed a hard coagulum floating on the surface.

On June 18 samples were again taken from cows 205, 209, and 403, were cooled to 10° C., and placed in the ice box. Twenty-four hours later a slightly abnormal taste was observed in 209, while the same taste, but much stronger, was observed in 205; the sample from 403 remained normal.

June 19 further samples were taken from the three cows above mentioned. No abnormal conditions could be observed in the samples when fresh, although a slight difference in flavor could be detected, making it possible to distinguish one sample from the other in this manner. An examination 14 hours later showed the sample from No. 403 was still normal, while the mixed samples of 209 and 205 had a slightly abnormal taste of the kind previously mentioned. This abnormal condition in the latter sample became rapidly worse.

Accurate observations were not made regarding the milk of cow 118, although the same abnormal taste was observed at the close of the lactation period.

The cause of this abnormal condition of the milk was not determined. The observations made showed conclusively that it was found only in the milk of certain cows near the end of the lactation period and that it was not in the milk when drawn from the cow, although even then the milk could be distinguished by taste from that produced by cows that were in the beginning or middle of the lactation period. The abnormal conditions described appeared within 12 hours and continued to increase as the milk became older. The abnormal condition developed freely within 12 hours when the milk was cooled to below 10° C. immediately after milking and kept at that temperature. This latter statement suggests that it was not the action of bacteria, as at 10° C. any common organism will grow so slowly that a decomposition of the milk to the extent of producing a strong rancid odor and bitter flavor within 12 hours can hardly be expected.

Numerous inquiries are received each year regarding abnormal flavor in milk from cows near the end of the lactation period. The conditions described in this correspondence indicate that the abnormal taste and odor found in the milk of certain of the experimental animals is not uncommon in the milk of cows kept under commercial conditions.

SUMMARY.

1. Eleven purebred cows, consisting of 2 Ayrshires and 3 each of the Jersey, Holstein-Friesian, and Shorthorn breeds, were kept through an entire lactation period on a ration of uniform composition consisting of 2 parts of alfalfa hay to 1 part of grain. The latter was a mixture of 1 part oats, 1 part bran, and 8 parts cornmeal. This ration was varied in quantity to suit the individual animal. The cows were kept under normal conditions except in regard to the uniformity of the ration, and all remained in good health. The milk and fat produced were normal for the breeds.

The object of the investigation was primarily to study the effects during a normal period of lactation upon the composition and properties of the milk, disregarding changes that might be due to other sources.

2. Composite samples were prepared from the milk of each cow by 7-day periods. The following analyses and determinations were made: Specific gravity, dry matter, total nitrogen, nitrogen as casein, nitrogen as albumin, fat, sugar, and ash. The physical constants of the fat were determined as follows: Relative size of the fat globules, Reichert-Meissl number, iodin number, saponification number, refractive index, and melting point. The methods of the Association of Official Agricultural Chemists were followed.

3. The total protein was found to be abnormally high following parturition and continued to decline until the third or fourth week, when the minimum was reached. It then remained fairly constant until near the end of the lactation period, when it rose rapidly and reached the maximum at the end of the period. The range in the total protein on the average was more than that for the fat.

The casein constituted 80 to 82 per cent of the total protein and seldom went beyond these limits. It showed the same changes during the lactation period as described for the total protein.

The determination of the nitrogen as albumin by the official method was unsatisfactory. Eliminating minor variations, the albumin bears almost a constant ratio to the total protein and therefore follows the same variations during the lactation period.

On the average, 81.4 per cent of the total protein is casein, and from 7 to 9 per cent was determined as albumin. No relation was found between the protein and the sugar.

4. The per cent of fat on the average declined during the first 3 months, followed by a period of 4 to 5 months with but little change. From this point a rapid increase was found to the end of the lactation period.

The variations in the fat and protein were on the whole quite similar. Sudden variations in the per cent of fat are, however, not accompanied by corresponding changes in the protein, but gradual changes in the fat go with corresponding variations in the protein. On the average there is 0.86 pound of protein and 0.71 pound of casein to 1 pound of fat. Therefore, for each pound of protein on the average there was found 1.16 pounds of fat.

5. The lactose is the least variable of the constituents except the ash. The only change that is attributable to the stage of lactation is a slight decline near the close.

6. The total solids show the same variation as the fat and protein, i. e., a slight decline at first, then practically no change for 8 or 9 months, followed by a rapid increase to the end of the lactation period.

The total protein averaged 27 per cent of the total solids, the casein 22.1 per cent, the albumin 2.3 per cent, fat 31.3 per cent, sugar 37 per cent, ash 5.3 per cent.

7. Ash determinations were not made on the 7-day samples. They were made by combining 4 of the 7-day samples. The amount of ash was quite uniform through the lactation period except near the end, when there was some increase accompanying the increase in the total solids.

8. The milk of 5 additional Jersey cows was analyzed practically through a lactation period. The rations given these cows were not entirely uniform for the year. The cows were kept farrow and at a uniform weight.

The range of variation in the milk of these cows was less than with those kept under normal conditions. The per cent of both nitrogen and fat remained practically stationary with no increase even at the end of 12 months.

9. The stage of lactation exerts a marked and uniform effect upon the relative size of the fat globules. The fat globules are especially large immediately after the beginning of the milking period, then the relative size declines sharply during the first 6 weeks, remains fairly constant for 5 or 6 months, after which the decline is much more rapid to the end of the lactation period. Variation in the relative size can not be correlated with the variation of any of the constituents of the milk. The Reichert-Meissl number is the only physical constant of the fat that can be correlated in any way with the relative size of the fat globules. The data indicate that the small fat globules are accompanied by a low Reichert-Meissl number.

10. The melting point of the butterfat was not influenced to any great extent by the stage of lactation. During the first few weeks there is a lack of uniformity in results, in some cases a high melting point in the beginning and in others a low. The high melting point in the beginning of the lactation period which occurs in most cases is probably brought about by the animal utilizing the body fat, since the ration fed at that stage of lactation is usually below the require-

ments of the body. After the first few weeks the melting point remains practically constant until near the end of the lactation period, when it rises. The rise in the melting point is accompanied by a high iodin number and an especially low Reichert-Meissl number. On the whole the melting point is little affected by the period of lactation when the food is kept uniform, except at the latter end, when abnormal figures may be expected.

11. The refractive index was not affected to any appreciable extent by the stage of lactation.

12. The Reichert-Meissl number showed a uniform decline on the average from the beginning to the end of the lactation period. Of the total number of analyses, 41.6 per cent came below 25, which is the standard set as a commercial limit for butter, while 7.5 per cent of the total number came below 20. In the beginning of the lactation period the variations in the Reichert-Meissl number were irregular. From this time on there was a gradual decline until near the end, when it became more marked. The Reichert-Meissl number is more influenced by the stage of lactation than any other of the physical constants except the relative size of the fat globules.

13. The iodin number ranged from 23.8 to 49.4, while 47.4 per cent of the whole were between 30 and 35. A lack of uniformity is found in the beginning of the lactation period. After this stage is passed there is a slight but gradual increase until near the end, when it increases more rapidly until the highest point is reached at the end.

14. The stage of lactation exerts a uniform effect upon the saponification value. There is a uniform decline from the beginning to the end of the lactation period, with the exception that the decline is more rapid during the last 3 months. The decline is uniform with the decrease in volatile acids. The lowest figure among the 488 determinations was 200.1, and the highest 252.3, while 80.6 per cent of the total number came between 220 and 235.

15. The churning of the cream became more difficult toward the end of the lactation period, and with some cows samples were found that could not be churned under any conditions.

16. An abnormal odor and flavor developed in the milk of certain cows when near the end of the lactation period. This condition was not present in the freshly drawn milk but appeared within 12 hours, even when the milk was held at 10° C.

APPENDIX.

As previously mentioned, a composite sample of the milk of each cow in this investigation was taken every 7 days. The detailed analyses of these 7-day samples for each of the 11 cows is given in Table I.

TABLE I.—*Analysis of the milk of each cow, by 7-day periods.*

COW NO. 4.

Week ending—		Specific gravity of milk.	Total nitrogen.	Casein nitrogen.	Albumin nitrogen.	Fat.	Water.	Total solids.	Solids not fat.	Sugar.	Reichert-Meissl number.	Iodin number.	Saponification number.	Refractive index.	Melting point.	Relative size of globules.
1906.			*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*					°*C.*	
Dec.	1	1.0300	0.52	0.46	......	5.60	......	......	......	......	27.52	36.10	231.2	1.4602	32.35	524
	8	1.0310	.52	......	0.052	5.37	......	......	......	4.80	32.06	32.13	228.6	1.4603	32.65	332
	15	1.0340	......	.41	.066	5.10	......	......	......	5.00	29.40	30.64	233.4	1.4602	32.35	333
	22	1.0340	......	......	......	4.62	85.87	14.13	9.51	4.88	27.88	25.43	231.1	1.4598	32.10	264
	29	1.0320	.57	......	.059	4.95	......	......	......	5.08	30.67	29.90	230.3	1.4594	32.35	420
1907.																
Jan.	5	1.0330	.49	.40	.048	4.35	......	......	......	5.40	27.43	25.15	234.5	1.4597	32.25	441
	12	1.0340	.55	.40	.058	4.60	......	......	......	4.95	29.06	28.78	235.2	1.4594	33.13	540
	19	1.0340	.51	.34	.057	4.60	......	......	......	4.51	27.72	28.34	232.2	1.4596	32.80	289
	26	1.0335	......	......	......	4.40	......	......	......	4.97	27.81	......	233.8	......	......	....
Feb.	2	1.0332	.53	.46	.047	5.10	......	......	......	4.87	28.05	28.14	231.9	1.4598	33.77	366
	9	1.0340	.60	.47	.058	5.60	......	......	......	4.64	29.67	30.62	231.6	1.4576	32.55	422
	16	1.0345	.58	.51	.066	5.17	......	......	......	5.00	28.55	30.06	234.2	1.4596	33.85	321
	23	1.0344	.58	.47	.062	4.60	......	......	......	5.16	31.13	28.43	233.3	1.4594	33.41	218
Mar.	2	1.0332	.61	.49	.081	5.07	85.61	14.39	9.32	5.22	27.80	27.90	230.1	1.4593	33.37	242
	9	1.0345	.62	.51	.067	4.66	85.60	14.40	9.74	5.46	27.86	29.78	223.8	1.4596	33.06	207
	16	1.0337	.62	.49	.059	5.06	85.46	14.54	9.48	5.22	27.22	33.64	229.1	1.4593	33.15	255
	23	1.0330	.59	.46	.050	4.93	85.59	14.41	9.48	4.90	28.88	32.09	230.4	1.4590	33.17	353
	30	1.0336	.59	.48	.043	4.83	85.82	14.18	8.35	5.10	30.26	37.26	228.8	1.4590	33.50	318
Apr.	6	1.0345	.61	.48	.062	4.80	85.74	14.26	9.46	5.48	27.36	28.03	232.4	1.4597	33.08	239
	13	1.0340	.62	.49	.023	4.68	......	......	......	5.00	29.32	27.96	231.3	1.4596	33.45	156
	20	1.0340	.62	.50	.029	5.02	85.69	14.31	8.29	5.08	31.88	26.88	230.6	1.4591	33.27	251
	27	1.0337	.58	.47	.031	4.83	86.01	13.99	9.16	4.88	28.53	27.93	229.5	1.4588	33.20	241
May	4	1.0330	.56	.47	.037	5.14	85.82	14.18	9.04	5.14	28.07	30.39	224.2	1.4596	33.30	199
	11	1.0340	.58	.49	.027	5.00	85.89	14.11	9.11	4.95	28.32	26.93	231.8	1.4591	34.00	250
	18	1.0315	.59	.47	.044	4.97	86.02	13.98	9.01	4.40	25.77	29.17	229.2	1.4591	33.30	207
	25	1.0335	.60	.50	.058	4.68	86.15	13.85	9.17	4.63	21.89	33.72	225.6	1.4596	32.40	474
June	1	1.0325	.55	.42	.089	4.77	86.12	13.88	9.11	4.08	28.67	31.50	227.2	1.4596	33.15	266
	8	1.0330	.60	.49	.066	4.50	86.24	13.76	9.26	4.44	29.54	......	229.3	1.4572	32.90	249
	15	1.0322	.58	.47	.054	4.38	86.52	13.48	9.10	......	27.85	29.59	228.5	1.4593	33.15	346
	22	1.0331	.58	.47	.063	4.44	86.39	13.61	9.17	4.43	27.83	29.60	229.5	1.4591	32.97	217
	29	1.0330	.58	.45	.066	4.26	85.77	14.23	9.97	4.26	29.06	29.83	229.9	1.4594	33.55	336
July	6	1.0323	.54	.46	.061	4.94	......	......	......	4.67	29.77	29.98	229.6	1.4598	33.30	374
	13	1.0340	.59	.47	.068	4.80	......	......	......	......	......	......	......	......	......	362
	20	1.0330	.61	.50	.046	4.89	......	......	......	4.52	25.75	32.91	227.3	1.4600	32.90	198
	27	1.0336	.64	.51	.057	4.57	86.04	13.96	9.39	4.67	25.44	31.34	231.5	1.4580	32.85	190
Aug.	3	1.0330	.63	.50	.076	4.65	86.71	13.29	8.64	4.83	24.52	32.55	244.4	1.4562	33.35	161
	10	1.0340	.63	.50	.071	4.85	85.97	14.03	9.18	4.73	25.90	31.49	248.1	1.4593	32.80	186
	17	1.0340	.66	.53	.061	5.15	85.30	14 70	9.55	4.83	25.81	31.42	246.2	1.4577	32.30	184
	24	1.0340	.70	.53	.054	4.82	85.45	14.55	9.73	4.44	26.50	32.62	227.2	1.4597	33.20	141
	31	1.0328	.65	.51	.058	5.39	85.25	14.75	9.86	4.56	25.66	33.05	230.5	1.4574	33.52	189
Sept.	7	1.0340	.67	.53	.069	5.68	85.20	14.80	9.12	4.42	25.87	32.18	227.6	1.4577	33.02	137

Table I.—*Analysis of the milk of each cow, by 7-day periods*—Continued.

COW NO. 99.

Week ending—	Specific gravity of milk.	Total nitrogen.	Casein nitrogen.	Albumin nitrogen.	Fat.	Water.	Total solids.	Solids not fat.	Sugar.	Reichert-Meissl number.	Iodin number.	Saponification number.	Refractive index.	Melting point.	Relative size of globules.
1907.		*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*					*°C.*	
Jan. 12	1.0340	0.55	0.43	0.054	5.00	......	......	......	5.10	30.70	29.38	229.2	1.4604	21.25	865
19	1.0340	.52	.44	.042	5.45	......	......	......	4.87	30.40	......	225.7	1.4602	21.30	561
26	1.0320	.51	.40	.022	5.25	......	......	......	5.02	29.86	34.25	238.0	1.4602	......	435
Feb. 2	1.0315	.46	.42	.033	5.17	......	......	......	4.78	29.69	34.41	229.3	1.4596	32.27	361
9	1.0330	.51	.41	.074	5.20	......	......	......	......	27.09	28.31	237.1	1.4602	33.55	508
16	1.0320	.52	......	.047	5.00	......	......	......	5.18	29.52	30.38	233.5	1.4594	32.65	361
23	1.0326	.49	.40	.041	4.60	......	......	......	4.93	28.02	30.46	229.8	1.4595	33.17	203
Mar. 2	1.0333	.50	.42	.052	4.37	86.91	13.09	8.72	5.33	30.89	28.69	228.0	1.4597	33.57	282
9	1.0334	.53	.45	.067	4.55	86.46	13.54	8.99	5.55	31.99	29.64	226.0	1.4594	32.60	305
16	1.0330	.51	.41	.027	4.51	86.51	13.49	8.98	5.27	32.04	32.94	231.3	1.4594	33.10	273
23	1.0340	.48	.35	.026	4.53	86.57	13.43	8.90	4.40	31.37	27.11	230.0	1.4592	33.50	418
30	1.0326	.50	.40	.027	4.14	87.28	12.72	8.58	5.45	32.95	26.13	230.7	1.4588	34.22	305
Apr. 6	1.0323	.48	.39	.024	4.50	86.80	13.20	8.70	5.01	30.99	26.80	231.7	1.4592	33.97	252
13	1.0327	.50	.42	.029	3.86	87.13	12.87	9.01	5.10	31.33	26.70	234.1	1.4594	34.07	233
20	1.0329	.51	.41	.024	4.74	86.50	13.50	8.76	5.17	31.52	28.16	231.6	1.4587	34.72	283
27	1.0324	.47	.39	.024	4.50	86.96	13.04	8.54	4.90	29.97	25.34	231.9	1.4584	35.35	328
May 4	1.0320	.46	.39	.022	4.39	87.16	12.84	8.45	5.18	......	......	......	......	......	259
11	1.0330	.50	.41	.021	4.32	87.05	12.95	8.63	5.18	30.90	28.55	229.4	1.4594	34.00	229
18	1.0327	.48	.38	.031	4.31	87.12	12.88	8.57	4.64	28.76	28.35	230.1	......	34.15	293
25	1.0310	.51	.40	.040	4.28	87.01	12.99	8.71	5.15	23.34	33.07	223.6	1.4600	33.20	275
June 1	1.0318	.47	.39	.048	4.32	87.13	12.87	8.55	4.68	31.51	28.41	232.2	1.4592	33.55	335
8	1.0322	.51	.40	.046	4.23	87.16	12.84	8.61	4.57	31.34	......	230.0	1.4593	34.83	305
15	1.0305	.48	.40	.037	4.43	87.10	12.90	8.47	4.48	30.79	26.17	231.8	1.4588	33.85	538
22	1.0310	.48	.39	.039	3.90	87.58	12.42	8.52	4.25	......	......	232.6	1.4588	......	217
29	1.0310	.47	.39	.036	4.27	86.96	13.04	8.77	4.38	30.16	23.80	225.9	1.4594	34.30	267
July 6	1.0320	.47	.38	.040	4.20	......	......	......	5.03	23.89	33.28	223.8	1.4603	33.45	259
13	1.0300	.49	.39	.041	4.40	......	......	......	3.96	......	......	......	......	......	618
20	1.0320	.49	.39	.028	4.56	......	......	......	4.71	27.04	26.70	232.1	1.4592	34.45	334
27	1.0309	.47	.38	.031	3.93	87.33	12.67	8.74	4.38	26.96	27.18	230.2	1.4571	34.55	736
Aug. 3	1.0320	.50	.41	.038	4.30	87.50	12.50	8.20	5.85	27.50	27.32	248.4	1.4569	34.30	265
10	1.0330	.51	.39	.048	4.42	86.87	13.13	8.71	5.25	26.81	27.68	231.4	1.4590	33.95	242
17	1.0330	.50	.40	.047	4.07	87.05	12.95	8.88	5.06	28.08	27.29	249.0	1.4588	34.50	224
24	1.0340	.52	.42	.041	4.37	86.87	13.13	8.76	4.53	27.76	28.47	228.2	......	34.37	182
31	1.0325	.52	.41	.030	4.80	86.66	13.34	8.54	4.41	27.42	28.70	234.4	1.4531	35.17	328
Sept. 7	1.0327	.51	.41	.041	4.70	86.34	13.66	8.96	4.78	27.16	28.52	233.8	1.4570	35.10	209
14	1.0320	.52	.45	.029	4.63	86.74	13.26	8.63	4.76	25.78	29.16	240.7	1.4546	33.92	359
21	1.0324	.54	.45	.036	4.74	86.15	13.85	9.11	4.80	22.93	28.11	233.9	1.4547	34.40	212
28	1.0355	.57	.45	.043	4.71	86.00	14.00	9.29	4.94	27.34	28.96	231.4	1.4549	34.15	202
Oct. 5	1.0345	.57	.45	.042	5.08	85.45	14.55	9.47	4.98	23.31	28.61	229.8	1.4564	34.10	226
12	1.0325	.57	.48	.049	5.39	85.34	14.66	9.27	5.38	29.72	29.53	230.3	1.4571	32.60	196
19	1.0340	.60	.50	.037	5.26	85.17	14.83	9.57	5.05	28.29	28.98	233.8	1.4564	34.35	195
26	1.0350	.61	.55	.033	5.78	84.68	15.32	9.54	5.18	21.74	26.38	231.5	1.4565	34.45	244
Nov. 2	1.0360	.64	.48	.046	6.00	84.39	15.61	9.61	5.08	25.30	24.62	227.9	1.4565	35.70	357
9	1.0323	.61	.50	.051	5.42	85.15	14.85	9.43	4.78	23.60	30.45	224.4	1.4561	35.00	255
16	1.0346	.64	.53	.068	5.99	84.11	15.89	9.90	5.28	21.99	27.62	224.0	1.4569	33.55	283
23	1.0335	.67	.52	.058	6.15	83.89	16.11	9.96	5.36	18.65	29.90	217.0	1.4553	34.95	367
30	1.0349	.68	.54	.087	6.07	83.76	16.24	10.17	6.20	14.64	31.12	217.7	1.4579	34.55	294

Table I.—*Analysis of the milk of each cow, by 7-day periods*—Continued.

COW NO. 118.

Week ending—	Specific gravity of milk.	Total nitrogen.	Casein nitrogen.	Albumin nitrogen.	Fat.	Water.	Total solids.	Solids not fat.	Sugar.	Reichert-Meissl number.	Iodin number.	Saponification number.	Refractive index.	Melting point.	Relative size of globules.
1906.		P.ct.	P.ct.	P.ct.	P.ct.	P.ct.	P.ct.	P.ct.	P.ct.					°C.	
Oct. 13	......	......	......	......	......	......	......	......	......	28.75	42.54	232.6	1.4606	17.57	....
20	......	......	......	......	......	......	......	......	......	32.59	38.29	228.6	1.4604	30.47	....
27	......	......	......	......	......	......	......	......	......	27.29	37.11	224.4	1.4603	31.82	....
Nov. 3	......	......	......	......	......	......	......	......	......	......	......	......	......	......	....
10	1.0300	0.48	......	......	5.06	86.07	13.93	8.87	4.60	24.97	34.37	226.6	1.4610	......	....
17	......	......	......	......	......	......	......	......	......	......	......	......	......	......	....
24	1.0310	.54	......	0.081	5.10	85.81	14.19	9.09	4.43	22.33	37.19	223.8	1.4606	32.82	....
Dec. 1	1.0297	.52	0.32	......	5.77	85.88	14.12	8.35	4.39	22.55	37.42	223.6	1.4608	32.50	1280
8	1.0229	.55	.49	.040	5.80	......	......	......	......	22.11	37.35	223.5	1.4609	32.72	449
15	1.0320	......	.46	.057	5.60	......	......	......	......	23.11	26.76	235.4	1.4603	33.55	441
22	1.0320	......	......	.033	5.58	85.45	14.55	8.97	4.66	25.98	33.32	231.7	1.4603	33.20	348
29	1.0340	.57	......	.073	5.20	......	......	......	4.73	25.36	32.71	227.7	1.4602	33.75	431
1907.															
Jan. 5	1.0335	.51	.42	......	5.00	......	......	......	5.51	24.82	26.18	229.1	1.4600	33.15	492
12	1.0320	.50	.38	.081	5.40	......	......	......	4.32	23.76	25.30	230.2	1.4603	33.37	1690
19	1.0320	.55	.42	.058	5.00	......	......	......	4.15	23.46	32.15	225.5	1.4601	33.40	710
26	1.0320	.58	.46	.033	5.05	......	......	......	4.25	22.73	31.13	231.0	1.4603	......	625
Feb. 2	1.0336	.58	.53	.036	5.00	......	......	......	4.85	23.97	31.58	227.4	1.4599	33.97	435
9	1.0345	.65	.56	.088	5.32	......	......	......	4.74	23.07	32.26	233.3	1.4602	33.67	394
16	1.0331	.70	......	.084	5.70	......	......	......	4.95	23.80	30.60	234.3	1.4598	34.07	342
23	1.0348	.65	.53	.086	6.00	......	......	......	4.77	24.77	31.74	225.9	1.4600	33.47	260
Mar. 2	1.0340	.64	.51	.087	5.80	84.90	15.10	9.30	5.01	24.71	29.96	227.4	1.4599	33.60	366
9	1.0350	.67	.53	.078	5.60	84.60	15.40	9.80	5.50	22.27	31.40	222.9	1.4597	32.90	374
16	1.0345	.66	.54	.058	5.69	84.59	15.41	9.72	5.22	25.59	31.53	225.7	1.4597	33.30	238
23	1.0345	.62	.51	.062	5.76	84.70	15.30	9.54	5.10	26.00	28.81	230.3	1.4589	33.80	512
30	1.0342	.64	.52	.042	5.44	85.29	14.71	9.27	5.03	27.56	27.83	231.0	1.4596	34.32	346
Apr. 6	1.0340	.67	.53	.048	5.86	84.72	15.28	9.42	5.15	27.47	28.91	230.8	1.4596	33.40	290
13	1.0350	.68	.53	.058	5.57	......	......	......	5.30	26.39	29.20	230.5	1.4595	33.75	342
20	1.0345	.67	.57	.049	5.87	84.51	15.49	9.62	5.32	25.23	28.74	225.1	1.4598	34.22	224
27	1.0345	.64	.53	.062	6.10	84.50	15.50	9.40	5.02	24.88	32.29	228.8	1.4600	33.42	337
May 4	1.0350	.63	.54	.053	5.95	83.88	16.12	10.17	5.53	20.84	33.99	225.9	1.4601	33.80	340
11	1.0350	.66	.56	.046	5.28	84.65	15.35	10.07	5.55	24.09	32.99	220.2	1.4602	33.65	336
18	1.0340	.64	.53	.067	5.86	84.53	15.47	9.61	5.50	22.66	30.69	224.2	1.4603	33.77	323
25	1.0350	.66	.53	.060	5.37	84.64	15.36	10.00	4.58	25.22	31.56	228.5	1.4600	33.55	240
June 1	1.0338	.64	.51	.061	5.41	84.80	15.20	9.80	4.43	25.28	35.37	221.6	1.4600	33.95	283
8	1.0340	.64	.50	.065	4.89	85.45	14.55	9.66	4.52	25.22	34.70	224.5	1.4604	33.25	351
15	1.0334	.62	.50	.063	4.99	85.94	14.06	9.07	4.73	24.42	33.03	225.8	1.4601	32.80	467
22	1.0320	.63	.51	.071	4.51	86.02	13.98	9.47	4.48	24.62	30.51	226.2	1.4596	33.57	189
29	1.0350	.63	.49	.071	4.83	85.17	14.83	10.00	4.72	22.00	32.53	227.9	1.4574	33.72	331
July 6	1.0342	.66	.50	.064	5.00	85.47	14.53	9.53	5.20	21.94	31.26	228.6	1.4596	33.47	230
13	1.0330	.65	.51	.070	3.54	......	......	......	4.52	......	......	......	......	......	286
20	1.0350	.65	.51	.050	5.00	......	......	......	4.55	23.73	30.42	228.9	1.4598	33.08	348
27	1.0342	.65	.51	.058	4.61	85.67	14.33	9.72	4.50	22.48	31.80	228.0	1.4561	34.55	523
Aug. 3	1.0354	.65	.51	.065	5.15	85.35	14.65	9.50	5.45	22.30	31.38	246.3	1.4555	34.15	228
10	1.0350	.65	.51	.075	4.57	85.71	14.29	9.72	5.10	22.64	30.95	244.6	1.4597	33.47	268
17	1.0350	.67	.53	.063	5.21	85.45	14.55	9.34	5.10	23.56	30.85	228.7	1.4595	33.80	210
24	1.0360	.70	.54	.060	4.86	85.07	14.93	10.07	4.76	21.31	32.19	224.1	1.4599	33.60	191
31	1.0345	.69	.53	.072	5.54	84.75	15.25	9.71	4.63	21.19	34.97	219.4	1.4604	33.33	291
Sept. 7	1.0370	.74	.58	.064	5.49	84.42	15.58	10.09	4.37	14.82	31.86	223.3	1.4569	33.97	222
14	1.0350	.78	.64	.060	5.74	83.70	16.30	10.56	4.30	6.10	41.83	217.0	1.4572	32.40	871
21	1.0350	.72	.61	.057	5.42	84.25	15.75	10.33	4.25	19.36	33.87	228.2	1.4564	34.75	314
28	1.0395	.77	.61	.078	5.14	83.74	16.26	11.12	4.90	23.02	36.65	221.1	1.4555	34.10	194
Oct. 5	1.0350	.74	.58	.049	5.60	......	......	......	4.40	8.45	41.56	211.7	1.4590	32.60	373
12	1.0335	.68	.55	.078	6.29	83.82	16.18	9.89	4.75	20.22	37.42	223.7	1.4579	33.55	720
19	1.0360	.86	.61	.062	5.81	82.66	17.34	11.53	5.81	10.70	37.64	217.1	1.4582	29.60	278
26	1.0370	.76	.57	.047	7.30	82.03	17.97	10.67	5.11	11.70	32.41	216.5	1.4575	37.35	386

TABLE I.—*Analysis of the milk of each cow, by 7-day periods*—Continued.

COW NO. 205.

Week ending—	Specific gravity of milk.	Total nitrogen.	Casein nitrogen.	Albumin nitrogen.	Fat.	Water.	Total solids.	Solids not fat.	Sugar.	Reichert-Meissl number.	Iodin number.	Saponification number.	Refractive index.	Melting point.	Relative size of globules.
1907.		*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*					°*C.*	
July 27	1.0332	0.54	0.43	0.048	3.76	87.39	12.61	8.83	3.98	22.95	41.82	......	1.4596	36.53	369
Aug 3	1.0340	.51	.40	.039	3.19	87.92	12.08	8.89	4.49	27.86	30.81	241.4	1.4587	32.97	197
10	1.0340	.46	.38	.049	2.69	88.68	11.32	8.63	5.24	29.32	38.03	244.2	1.4605	32.17	152
17	1.0340	.46	.37	.029	3.30	89.05	10.95	7.65	5.03	26.52	37.83	241.1	1.4605	31.98	248
24	1.0340	.44	.35	.034	3.05	88.12	11.88	8.83	4.94	24.97	35.61	229.1	1.4574	32.50	130
31	1.0325	.43	.35	.028	3.14	88.20	11.80	8.66	4.81	......	......	......	......	......	176
Sept. 7	1.0330	.42	.35	.040	3.38	88.41	11.59	8.21	5.01	27.34	30.62	229.1	1.4603	33.45	131
14	1.0314	.44	.35	.026	3.00	88.97	11.03	8.03	5.15	25.73	37.40	229.8	1.4580	32.05	151
21	1.0320	.43	.35	.025	2.81	88.00	12.00	9.19	4.99	26.23	32.93	231.3	1.4549	33.25	204
28	1.0345	.45	.33	.033	3.01	88.33	11.67	8.66	4.99	25.29	31.65	230.8	1.4543	33.55	142
Oct. 5	1.0330	.46	.35	.042	3.17	88.34	11.66	8.49	4.55	28.05	32.20	230.6	1.4579	33.67	123
12	1.0315	.41	.33	.025	3.07	88.54	11.46	8.39	......	25.73	36.15	223.2	1.4565	33.10	124
19	1,0325	.44	.35	.030	3.10	88.05	11.95	8.85	5.20	24.45	33.08	234.1	1.4575	33.52	129
26	1,0330	.44	.36	.033	3.10	88.36	11.64	8.54	5.26	26.82	31.89	239.7	1.4562	33.05	183
Nov. 2	1.0335	.44	.35	.029	3.58	87.55	12.45	8.87	5.24	27.49	32.14	230.2	......	34.55	148
9	1.0314	.44	.36	.036	3.21	88.24	11.76	8.55	5.03	30.76	30.30	227.7	1.4577	33.90	127
16	1.0321	.45	.37	.031	3.33	87.80	12.20	8.87	4.95	29.71	30.97	235.1	1.4554	33.05	147
23	1.0312	.45	.37	.032	3.34	88.05	11.95	8.61	5.09	29.25	31.27	231.1	1.4576	33.27	128
30	1.0325	.45	.37	.036	3.32	88.04	11.96	8.64	5.73	27.92	31.54	229.6	1.4571	33.07	136
Dec. 7	1.0340	.45	.38	.037	3.17	87.66	12.34	9.17	5.91	24.38	33.29	227.3	1.4572	32.67	96
14	1.0337	.46	.38	.033	3.01	88.34	11.66	9.65	5.24	27.35	32.20	231.3	1.4568	32.88	81
21	1.0328	.44	.39	.032	3.30	88.30	11.70	8.40	5.18	26.39	32.77	228.8	1.4573	32.55	72
28	1.0330	.44	.36	.031	2.87	88.23	11.77	8.90	5.59	25.92	32.90	227.1	1.4571	32.98	87
1908.															
Jan. 4	1.0325	.45	.37	.033	3.06	88.04	11.96	8.90	5.42	28.01	32.68	227.4	1.4573	33.30	88
11	1.0330	.45	.37	.034	3.54	87.81	12.19	8.65	5.01	26.72	32.81	228.0	1.4557	32.75	116
18	1.0320	.45	.37	.043	3.21	88.24	11.76	8.55	5.57	28.22	32.73	226.6	1.4572	32.73	105
25	1.0320	.46	.37	.037	3.38	87.87	12.13	8.75	4.96	28.88	31.45	227.3	1.4554	33.80	120
Feb. 1	1.0340	.45	.38	.032	2.89	88.17	11.83	8.94	5.27	28.37	33.50	230.3	1.4571	32.25	87
8	1.0330	.44	.37	.037	3.26	88.01	11.99	8.73	4.73	27.01	32.07	229.1	1.4570	32.73	112
15	1.0327	.44	.37	.034	3.19	87.90	12.10	8.91	4.50	27.02	34.46	226.9	1.4564	33.00	106
22	1.0327	.44	.38	.034	3.38	87.75	12.25	8.87	5.04	28.63	33.81	226.7	1.4564	33.10	85
29	1.0346	.44	.37	.039	3.15	87.69	12.31	9.16	4.75	27.44	33.46	225.3	1.4564	33.10	82
Mar. 7	1.0336	.48	.37	.020	3.17	87.94	12.06	8.89	4.97	28.98	33.20	225.4	1.4582	32.75	126
14	1.0326	.48	.37	.020	3.19	88.06	11.94	8.75	......	27.95	......	225.3	......	33.55	89
21	1.0325	.45	.36	.019	3.28	87.96	12.04	8.76	5.32	27.78	32.84	225.3	......	......	87
28	1.0330	.49	.41	.047	2.94	88.26	11.74	8.80	5.00	26.71	36.16	224.1	......	33.48	97
Apr. 4	1.0325	.48	.40	.058	3.23	87.99	12.01	8.78	4.87	27.38	35.29	224.3	......	32.78	88
11	1.0322	.48	.39	.027	3.36	87.90	12.10	8.74	5.02	23.32	37.69	220.2	......	34.25	82
18	1.0317	.47	.38	.024	3.38	87.85	12.15	8.77	5.45	26.72	35.26	224.7	......	32.53	113
25	1.0325	.48	.40	.019	3.26	87.80	12.20	8.94	5.13	26.83	33.94	226.3	......	32.80	78
May 2	1.0330	.50	.41	.034	3.25	88.10	11.90	8.65	5.32	25.52	35.28	227.5	......	32.90	88
9	1.0330	.52	.43	.039	3.27	87.73	12.27	9.00	5.15	25.45	34.98	225.1	......	32.85	61
16	1.0337	.48	.41	.031	3.22	87.58	12.42	9.20	5.10	27.14	34.88	228.1	......	33.35	75
23	1.0320	.52	.45	.035	3.50	87.81	12.19	8.69	4.94	24.41	36.44	224.5	......	32.95	98
30	1.0335	.55	.42	.035	3.74	87.29	12.71	8.97	4.82	21.83	36.89	222.1	......	31.76	90
June 6	1.03 6	.54	.47	.031	3.20	87.30	12.70	9.50	5.65	19.14	38.71	219.0	......	32.35	79
13	1.0335	.53	......	.034	3.63	87.04	12.96	9.33	4.63	21.78	37.03	223.2	......	32.75	227
20	1.0334	.56	.46	.051	3.40	88.36	11.64	8.24	4.98	18.82	37.48	219.0	......	33.30	70
27	1.0326	.60	.48	.030	3.82	87.01	12.99	9.17	4.78	14.72	41.34	215.8	......	36.35	59
July 4	1.0330	.57	.52	.019	3.68	86.97	13.03	9.35	4.91	16.11	42.07	215.9	......	36.15	111
11	1.0338	.57	.47	.032	3.61	87.42	12.58	8.97	4.78	12.61	41.89	208.5	......	......	112
18	1.0330	.62	.55	.017	3.61	86.46	13.54	9.93	5.10	7.63	44.96	200.1	......	52.90	127
25	1.0330	.62	.56	.017	4.00	86.30	13.70	9.70	5.17	10.96	42.89	202.7	......	50.25	177
Aug. 1	1.0336	.63	.56	.033	3.52	86.51	13.49	9.97	5.04	9.76	41.61	210.7	......	47.43	175
8	1.0332	.71	.60	.030	3.53	86.92	13.08	9.55	4.22	10.09	42.22	204.3	......	47.33	185

TABLE I.—*Analysis of the milk of each cow, by 7-day periods*—Continued.

COW NO. 206.

Week ending—		Specific gravity of milk.	Total nitrogen.	Casein nitrogen.	Albumin nitrogen.	Fat.	Water.	Total solids.	Solids not fat.	Sugar.	Reichert-Meissl number.	Iodin number.	Saponification number.	Refractive index.	Melting point.	Relative size of globules.
1907.			*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*					°*C.*	
June	8	1.0315	0.53	0.41	0.058	3.48	88.03	11.97	8.49	3.88	28.96	......	......	......	34.05	282
	15	1.0290	.43	.34	.036	3.17	88.96	11.04	7.87	4.12	28.47	37.21	225.3	1.4604	32.63	256
	22	1.0282	.40	.31	.038	2.58	90.05	9.95	7.37	......	32.47	29.80	234.8	1.4595	31.75	169
	29	1.0290	.39	.30	.037	3.06	89.16	10.84	7.78	4.21	30.69	26.00	232.1	1.4591	33.38	304
July	6	1.0293	.37	.30	.029	3.00	......	......	......	4.61	33.38	29.02	229.3	1.4591	32.45	237
	13	1.0290	.38	.29	.036	2.70	......	......	......	......	......	......	......	......	......	439
	20	1.0295	.40	.31	.019	3.19	......	......	......	4.33	28.80	28.64	231.6	1.4595	34.10	276
	27	1.0292	.37	.29	.029	2.63	89.90	10.10	7.47	4.54	26.27	34.06	223.9	1.4574	34.02	123
Aug.	3	1.0290	.37	.30	.025	2.76	89.96	10.04	7.28	4.70	26.38	38.76	243.5	1.4569	32.35	120
	10	1.0290	.38	.30	.035	2.29	90.38	9.62	7.33	4.48	29.66	34.24	247.9	1.4598	31.38	126
	17	1.0295	.37	.29	.026	2.70	88.98	11.02	8.32	4.31	28.31	35.11	246.7	1.4599	31.83	137
	24	1.0300	.37	.28	.034	2.58	89.96	10.04	7.46	4.25	28.24	34.00	231.4	1.4570	32.20	114
	31	1.0275	.38	.28	.022	2.94	89.77	10.23	7.29	4.00	24.70	34.02	229.5	1.4579	32.10	141
Sept.	7	1.0282	.38	.30	.028	2.76	90.01	9.99	7.23	4.06	22.91	27.60	235.4	1.4551	32.47	121
	14	1.0275	.40	.32	.019	2.96	89.73	10.27	7.31	4.10	27.60	34.72	232.8	1.4543	31.35	140
	21	1.0290	.40	.31	.018	2.71	89.43	10.57	7.86	4.80	23.09	30.47	236.9	1.4563	32.30	225
	28	1.0300	.42	.30	.033	3.10	89.43	10.57	7.47	4.19	25.56	29.80	231.9	1.4574	31.80	174
Oct.	5	1.0300	.42	.31	.035	2.72	89.57	10.43	7.71	4.32	30.63	34.65	233.1	1.4555	31.82	139
	12	1.0290	.39	.35	.020	2.94	89.33	10.67	7.73	4.23	30.23	32.58	231.9	1.4577	33.18	122
	19	1.0290	.44	.32	.022	2.78	89.51	10.49	7.71	4.28	22.35	30.13	232.5	1.4555	33.07	99
	26	1.0290	.42	.33	.033	3.06	89.60	10.40	7.34	3.66	......	......	......	......	......	147
Nov.	2	1.0300	.42	.32	.030	3.13	89.14	10.86	7.73	4.14	24.70	31.96	229.3	1.4551	33.05	196
	9	1.0278	.43	.33	.034	3.01	89.20	10.80	7.79	4.13	22.34	31.84	232.2	1.4574	32.35	130
	16	1.0286	.42	.34	.037	3.05	89.13	10.87	7.82	4.24	26.49	31.21	232.0	1.4576	32.00	147
	23	1.0281	.41	.31	.066	3.05	89.18	10.82	7.77	4.20	26.84	32.46	232.6	1.4547	32.55	159
	30	1.0290	.40	.31	.034	3.08	89.17	10.83	7.75	4.91	25.89	31.90	230.4	1.4572	32.40	120
Dec.	7	1.0290	.40	.30	.029	3.01	89.08	10.92	7.91	5.39	22.08	33.03	223.8	1.4575	33.40	138
	14	1.0290	.42	.32	.031	2.39	89.56	10.44	8.05	4.45	22.29	35.16	231.9	1.4582	32.20	112
	21	1.0295	.42	.33	.032	3.08	89.37	10.63	7.55	4.22	24.95	32.56	229.2	1.4574	32.92	103
	28	1.0290	.40	.32	.030	2.86	89.29	10.71	7.85	4.79	21.46	33.54	225.3	1.4574	33.38	103
1908.																
Jan.	4	1.0290	.46	.34	.037	2.82	89.00	11.00	8.18	4.30	23.67	35.84	223.7	1.4586	33.55	125
	11	1.0290	.45	.34	.046	3.23	89.15	10.85	7.62	3.69	23.49	35.06	224.0	1.4568	32.65	108
	18	1.0295	.43	.33	.040	3.09	89.13	10.87	7.78	4.35	20.80	33.77	224.2	1.4579	33.05	122
	25	1.0293	.44	.35	.036	3.13	88.95	11.05	7.92	3.58	24.01	34.76	226.1	1.4574	32.23	94
Feb.	1	1.0310	.45	.36	.030	2.70	89.07	10.93	8.23	4.19	25.41	34.03	222.6	1.4577	33.55	74
	8	1.0310	.44	.38	.038	3.06	88.81	11.19	8.13	4.23	23.89	33.06	224.6	1.4563	32.40	93
	15	1.0300	.45	.38	.034	2.93	88.72	11.28	8.35	3.50	23.08	34.99	222.5	1.4560	32.55	61
	22	1.0310	.49	.41	.028	3.35	87.90	12.10	8.75	4.06	21.46	......	220.3	1.4588	31.95	95
	29	1.0326	.53	.45	.048	3.03	87.82	12.18	9.15	4.09	......	......	218.2	1.4587	......	79
Mar.	7	1.0324	.56	.44	.045	3.03	87.97	12.03	9.00	4.09	17.73	35.55	218.5	1.4563	34.25	62
	14	1.0338	.65	.52	.044	3.39	87.13	12.87	9.48	4.30	19.97	33.25	223.4	......	33.13	84
	21	1.0343	.68	.54	.047	3.44	86.91	13.09	9.65	4.68	......	......	210.4	......	52.10	45
	28	1.0353	.74	.63	.073	3.05	......	......	......	4.54	15.27	37.62	215.4	......	35.15	54
Apr.	4	1.0346	.77	.61	.095	3.73	86.05	13.95	10.22	4.48	......	38.72	......	......	34.80	132

TABLE I.—*Analysis of the milk of each cow, by 7-day periods*—Continued.

COW NO. 209.

Week ending—	Specific gravity of milk.	Total nitrogen.	Casein nitrogen.	Albumin nitrogen.	Fat.	Water.	Total solids.	Solids not fat.	Sugar.	Reichert-Meissl number.	Iodin number.	Saponification number.	Refractive index.	Melting point.	Relative size of globules.
1907.		*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*					*°C.*	
July 27	1.0310	0.61	0.46	0.045	3.95	87.16	12.84	8.89	3.89	21.47	43.11	220.6	1.4587	32.17	710
Aug. 3	1.0320	.49	.39	.045	3.14	88.77	11.23	8.09	5.20	24.23	42.24	239.0	1.4596	33.85	237
10	1.0320	.44	.34	.045	2.59	89.56	10.44	7.85	4.17	28.46	36.82	244.6	1.4605	32.23	163
17	1.0320	.45	.36	.049	2.80	89.55	10.45	7.65	4.35	28.45	35.65	244.4	1.4604	32.08	174
24	1.0320	.45	.34	.029	2.40	89.80	10.20	7.80	4.15	......	......	......	......	......	110
31	1.0300	.43	.32	.033	2.64	89.91	10.09	7.45	3.51	26.82	31.40	236.2	1.4602	31.72	128
Sept. 7	1.0300	.44	.33	.040	2.68	89.78	10.22	7.54	4.14	27.39	36.16	223.4	1.4601	32.70	158
14	1.0298	.46	.37	.025	2.67	89.59	10.41	7.74	4.21	26.32	32.39	232.3	1.4562	32.05	158
21	1.0290	.43	.33	.024	2.54	89.01	10.99	8.45	4.00	20.99	34.01	234.1	1.4564	33.40	179
28	1.0303	.46	.34	.042	2.72	89.79	10.21	7.49	......	24.30	32.54	231.2	1.4559	31.45	122
Oct. 5	1.0310	.47	.35	.037	2.96	89.37	10.63	7.67	4.31	29.19	32.13	230.5	1.4572	32.55	118
12	1.0295	.44	.35	.043	2.72	89.30	10.70	7.98	4.20	25.92	32.86	230.7	1.4565	30.82	123
19	1.0290	.49	.36	.040	3.92	......	......	......	4.10	26.29	33.51	232.8	1.4576	31.15	175
26	1.0305	.46	.37	.032	3.00	89.23	10.77	7.77	3.38	27.14	32.70	232.5	1.4577	31.10	132
Nov. 2	1.0315	.46	.37	.039	3.09	88.61	11.39	8.30	4.23	27.39	33.09	227.4	......	33.23	139
9	1.0285	.47	.35	.039	2.96	88.96	11.04	8.08	4.10	27.37	33.11	230.4	1.4565	31.87	104
16	1.0286	.44	.38	.039	3.00	89.19	10.81	7.81	3.64	28.03	32.48	232.2	1.4571	32.75	92
23	1.0298	.45	......	.031	3.14	88.82	11.18	8.04	4.33	25.71	32.22	231.1	1.4579	33.00	120
30	1.0295	.43	.33	.040	3.35	88.79	11.21	7.86	5.30	22.08	36.05	223.3	1.4582	34.07	120
Dec. 7	1.0310	.47	.35	.025	3.05	88.59	11.41	8.36	......	23.44	33.36	226.4	1.4570	32.35	85
14	1.0308	.47	.36	.043	2.54	89.19	10.81	8.27	4.93	23.75	34.74	232.0	1.4575	32.12	65
21	1.0310	.46	.39	.045	3.24	88.54	11.46	8.22	4.28	26.70	33.57	230.6	1.4573	31.60	114
28	1.0300	.45	.36	.033	2.73	89.07	10.93	8.20	4.50	......	......	......	......	......	88
1908.															
Jan. 4	1.0295	.46	.33	.046	2.74	89.38	10.62	7.88	3.74	23.58	36.42	224.4	1.4575	31.35	87
11	1.0305	.51	.37	.045	3.00	88.80	11.20	8.20	3.88	22.62	37.19	221.8	1.4582	33.15	99
18	1.0300	.50	.41	.040	2.95	89.03	10.97	8.02	4.49	22.31	36.97	225.7	1.4580	32.05	94
25	1.0300	.50	.38	.049	3.08	88.56	11.44	8.36	3.96	24.35	36.08	225.3	1.4576	32.00	123
Feb. 1	1.0314	.49	.41	.042	2.72	88.80	11.20	8.48	4.32	21.89	36.22	223.3	1.4558	32.00	74
8	1.0310	.48	.40	.056	3.15	88.66	11.34	8.19	4.20	23.99	34.44	221.7	1.4579	33.00	122
15	1.0298	.49	.39	.042	2.95	89.13	10.87	7.92	4.31	22.28	35.88	218.5	1.4565	32.75	72
22	1.0309	.52	.40	.043	3.08	88.61	11.39	8.31	4.06	24.15	36.44	222.8	1.4573	33.45	82
29	1.0307	.48	.40	.046	2.87	88.70	11.30	9.43	3.20	......	......	226.6	1.4563	31.93	119
Mar. 7	1.0315	.53	.40	.044	2.94	88.47	11.53	8.59	4.17	22.78	36.78	222.3	1.4579	31.48	86
14	1.0315	.50	.41	.033	3.06	88.43	11.57	8.51	4.19	25.53	......	224.5	......	33.35	180
21	1.0310	.52	.41	.038	3.18	88.41	11.59	8.41	4.64	24.10	37.80	221.4	......	33.20	74
28	1.0313	.54	.43	......	2.85	88.38	11.62	8.77	4.72	24.52	36.46	219.6	......	33.38	78
Apr. 4	1.0313	.58	.46	.059	3.69	87.51	12.49	8.80	4.37	20.31	37.80	218.0	......	34.85	81
11	1.0322	.61	.46	.061	3.75	87.32	12.68	8.93	4.60	17.67	42.47	212.9	......	34.80	78
18	1.0330	.60	.51	.053	3.32	87.39	12.61	9.29	4.99	20.90	41.09	221.6	......	32.60	75
25	1.0333	.59	.52	.053	3.33	87.47	12.53	9.20	4.53	21.78	34.94	224.2	......	33.03	85
May 2	1.0326	.57	.46	.044	3.29	87.72	12.28	8.99	4.84	22.84	35.19	223.3	......	33.20	66
9	1.0335	.62	.50	.079	3.27	87.24	12.76	9.49	4.82	22.31	33.05	222.0	......	32.40	69
16	1.0356	.65	.54	.055	3.52	86.80	13.20	9.68	4.97	21.36	38.34	221.5	......	33.20	50
23	1.0360	.75	.62	.074	3.74	86.30	13.70	9.96	4.53	18.78	34.82	221.0	......	33.80	65
30	1.0344	.73	.59	.082	3.75	86.30	13.70	9.95	3.57	22.28	36.63	221.4	......	34.40	98
June 6	1.0370	.76	.60	.083	3.76	86.02	13.98	10.22	4.34	20.80	35.51	223.2	......	34.85	63
13	1.0344	.72	.61	.084	4.05	86.44	13.56	9.51	4.33	20.60	36.88	219.0	......	35.13	77
20	1.0335	.72	.56	.086	4.05	87.21	12.79	8.74	4.35	19.12	37.74	217.5	......	37.40	65
27	1.0330	.70	.59	.100	6.54	84.39	15.61	9.07	4.08	21.34	38.99	214.8	......	36.98	122
July 4	1.0314	.72	.57	.033	4.01	86.57	13.43	9.42	4.52	20.93	39.06	215.8	......	37.80	114

TABLE I.—*Analysis of the milk of each cow, by 7-day periods*—Continued.

COW NO. 300.

Week ending—		Specific gravity of milk.	Total nitrogen.	Casein nitrogen.	Albumin nitrogen.	Fat.	Water.	Total solids.	Solids not fat.	Sugar.	Reichert-Meissl number.	Iodin number.	Saponification number.	Refractive index.	Melting point.	Relative size of globules.
1908.			*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*					°*C.*	
Jan.	4	1.0340	0.61	0.49	0.039	4.17	86.24	13.76	9.59	5.55	31.38	32.95	238.6	1.4567	37.88	283
	11	1.0330	.53	.44	.048	4.32	86.61	13.39	9.07	5.05	28.45	34.89	229.5	1.4575	33.58	220
	18	1.0330	.50	.43	.042	3.89	87.44	12.56	8.67	5.16	22.90	30.07	230.8	1.4565	32.95	173
	25	1.0315	.48	.40	.027	3.65	87.43	12.57	8.92	4.81	27.89	32.42	231.3	1.4570	......	265
Feb.	1	1.0330	.46	.40	.030	3.22	87.96	12.04	8.82	4.74	28.69	29.49	228.7	1.4544	33.30	175
	8	1.0320	.46	.38	.031	3.94	87.60	12.40	8.46	4.29	29.23	28.25	230.2	1.4563	32.88	177
	15	1.0330	.48	.41	.037	3.65	87.65	12.35	8.70	4.95	28.21	29.60	232.8	1.4549	33.58	150
	22	1.0320	.46	.40	.024	3.61	87.72	12.28	8.67	5.26	29.69	27.47	231.0	1.4558	33.80	148
	29	1.0325	.47	.40	.033	3.31	87.87	12.13	8.82	4.99	26.86	28.35	233.5	1.4557	33.50	199
Mar.	7	1.0329	.49	.40	.027	3.37	87.72	12.28	8.91	4.04	27.12	25.95	233.7	1.4563	33.55	124
	14	1.0330	.48	.40	.017	3.45	87.83	12.17	8.72	4.24	29.20	28.34	229.8	....	33.35	141
	21	1.0320	.49	.38	.031	3.38	88.02	11.98	8.60	5.28	27.84	28.12	232.0	....	33.40	128
	28	1.0314	.50	.41	.039	3.36	87.93	12.07	8.71	5.14	26.07	28.10	227.7	....	33.78	157
Apr.	4	1.0302	.46	.37	.038	3.50	88.11	11.89	8.39	4.42	24.12	35.72	223.3	....	34.00	131
	11	1.0312	.46	.36	.025	3.23	88.30	11.70	8.47	4.93	26.10	......	220.7	....	33.50	123
	18	1.0305	.47	.37	.018	3.36	88.43	11.57	8.22	5.00	26.76	......	227.5	....	32.88	128
	25	1.0304	.46	.37	.031	3.15	88.42	11.58	8.43	5.02	27.45	27.31	227.8	....	33.70	130
May	2	1.0313	.44	.38	.037	3.47	88.04	11.96	8.49	4.98	26.31	29.55	227.9	....	33.50	119
	9	1.0320	.47	.40	.036	3.30	88.30	11.70	8.40	4.90	27.18	27.53	229.3	....	33.78	106
	16	1.0316	.46	.40	.021	3.35	88.62	11.38	8.03	4.94	26.38	25.61	231.6	....	33.99	106
	23	1.0301	.45	.39	.026	3.44	88.74	11.26	7.82	4.65	......	......	......	....	......	146
	30	....	.48	.38	.042	3.40	88.62	11.38	7.98	......	25.73	28.60	231.1	....	33.88	169
June	6	1.0302	.46	.37	.024	2.98	88.60	11.40	8.42	4.45	25.80	29.86	229.9	....	34.18	115
	13	1.0302	.49	.40	.025	3.20	88.66	11.34	8.14	4.62	25.74	30.38	229.4	....	33.55	101
	20	1.0305	.47	.39	.041	3.30	......	......	......	4.75	23.54	31.88	227.6	....	34.00	83
	27	1.0296	.46	.38	.028	3.46	88.60	11.40	7.94	4.79	24.76	34.23	224.3	....	34.48	112
July	4	1.0304	.45	.39	.020	3.34	88.66	11.34	8.00	4.67	24.53	37.87	224.1	....	33.45	94
	11	1.0295	.45	.41	.028	3.11	88.61	11.39	8.28	5.06	25.43	37.21	222.0	....	33.40	83
	18	1.0300	.49	.42	.015	3.72	87.70	12.30	8.58	4.75	23.93	37.26	221.3	....	33.10	63
	25	1.0310	.47	.44	.019	3.59	87.87	12.13	8.54	5.22	23.11	39.37	222.0	....	33.90	83
Aug.	1	1.0310	.49	.44	.022	3.26	88.11	11.89	8.63	5.21	24.01	37.12	221.9	....	33.15	75
	8	1.0316	.51	.47	.021	3.55	87.74	12.26	8.71	5.13	24.44	35.54	222.9	....	33.05	98
	15	1.0313	.53	.49	.018	3.47	87.93	12.07	8.60	5.24	24.95	36.62	220.9	....	34.00	85
	22	1.0315	.58	.53	.017	3.61	87.47	12.53	8.92	5.12	23.90	34.91	223.7	....	32.88	58
	29	1.0320	.57	.52	.020	3.89	87.24	12.76	8.87	5.15	23.25	35.75	228.2	....	32.55	70
Sept.	5	1.0330	.58	.53	.012	3.99	87.11	12.89	8.90	5.00	20.26	33.65	222.9	....	33.75	88
	12	1.0315	.61	.55	.020	4.40	86.54	13.46	9.06	4.95	19.09	36.60	219.3	....	33.95	170
	19	1.0325	.64	.57	.036	4.58	86.17	13.83	9.25	4.93	17.37	36.99	215.5	....	34.90	144
	26	1.0334	.71	.61	.022	4.45	86.03	13.97	9.52	3.94	17.43	39.64	216.7	....	33.28	129
Oct.	3	1.0300	.72	.61	.049	4.65	85.86	14.14	9.49	3.74	......	......	......	....	......	71

TABLE I.—*Analysis of the milk of each cow, by 7-day periods*—Continued.

COW NO. 301.

Week ending—		Specific gravity of milk.	Total nitrogen.	Casein nitrogen.	Albumin nitrogen.	Fat.	Water.	Total solids.	Solids not fat.	Sugar.	Reichert-Meissl number.	Iodin number.	Saponification number.	Refractive index.	Melting point.	Relative size of globules.
1907.			*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*					*°C.*	
Oct.	5	1.0355	0.64	0.53	0.049	4.11	86.29	13.71	9.60	4.96	31.93	26.89	238.0	1.4555	31.70	227
	12	1.0340	.57	.49	.050	3.89	86.66	13.34	9.45	5.35	32.03	30.22	235.7	1.4565	31.92	266
	19	1.0340	.54	.46	.034	3.56	87.06	12.94	9.28	5.26	30.70	26.92	238.9	1.4568	32.70	204
	26	1.0335	.50	.41	.038	3.90	87.20	12.80	8.90	5.11	27.70	30.30	235.1	1.4567	31.95	232
Nov.	2	1.0340	.49	.41	.035	3.98	86.98	13.02	9.04	4.77	27.11	27.87	235.5	1.4569	34.00	281
	9	1.0317	.50	.39	.022	3.58	87.46	12.54	8.96	4.91	27.95	31.79	230.0	1.4574	32.80	151
	16	1.0311	.50	.40	.034	3.69	87.63	12.37	8.68	4.75	28.11	29.90	232.3	1.4571	32.65	157
	23	1.0338	.49	.39	.035	3.71	87.95	12.05	8.34	4.44	25.19	30.08	238.6	1.4552	33.40	166
	30	1.0320	.48	.39	.032	3.75	87.64	12.36	8.61	5.77	25.79	31.31	232.6	1.4568	32.57	137
Dec.	7	1.0330	.49	.41	.047	3.83	87.39	12.61	8.78	5.67	25.88	31.46	229.6	1.4571	32.07	125
	14	1.0325	.48	.39	.046	3.80	87.36	12.64	8.84	5.43	27.17	30.70	233.1	1.4572	33.08	164
	21	1.0330	.47	.36	.041	3.85	87.34	12.66	8.81	......	27.48	28.77	232.8	1.4565	32.70	140
	28	1.0320	.50	.42	.030	3.71	87.26	12.74	9.03	5.34	27.24	29.16	232.8	1.4559	32.40	152
1908.																
Jan.	4	1.0325	.50	.42	.034	3.75	87.33	12.67	8.92	5.05	24.75	30.35	228.7	1.4564	33.00	184
	11	1.0320	.52	.43	.041	4.01	87.20	12.80	8.79	5.14	25.26	30.00	229.2	1.4562	32.90	171
	18	1.0330	.53	.44	.035	3.75	87.67	12.33	8.58	5.11	23.28	29.87	230.8	1.4565	32.90	113
	25	1.0325	.50	.43	.039	4.12	86.89	13.11	8.99	4.96	24.13	30.58	225.9	1.4568	33.60	146
Feb.	1	1.0326	.50	.42	.041	3.86	87.07	12.93	9.07	4.68	24.71	30.72	225.1	1.4568	34.85	148
	8	1.0336	.52	.43	.046	4.24	86.69	13.31	9.07	4.44	25.89	31.19	230.4	1.4561	33.70	206
	15	1.0324	.50	.42	.042	4.09	86.99	13.01	8.92	5.00	24.79	31.21	228.7	1.4553	33.23	161
	22	1.0328	.52	.43	.044	4.00	87.26	12.74	8.74	......	27.04	30.39	229.0	1.4559	32.80	126
	29	1.0336	.52	.43	.061	3.71	86.99	13.01	9.30	......	26.64	30.42	229.9	1.4561	33.48	345
Mar.	7	1.0329	.55	.42	.043	3.65	87.23	12.77	9.12	4.23	26.70	30.11	232.0	1.4575	32.75	122
	14	1.0330	.52	.42	.036	3.76	87.10	12.90	9.14	3.67	26.76	......	227.9	....	32.90	118
	21	1.0326	.50	.41	.034	4.07	87.10	12.90	8.93	5.83	25.35	32.99	218.1	....	33.95	116
	28	1.0330	.53	.43	.040	3.77	87.50	12.50	8.73	5.27	26.15	29.73	227.4	....	33.90	224
Apr.	4	1.0321	.50	.41	.051	4.00	87.74	12.26	8.26	5.09	26.50	29.58	226.2	....	34.13	164
	11	1.0320	.51	.41	.045	3.96	87.15	12.85	8.89	5.32	24.34	31.87	206.7	....	33.95	146
	18	1.0312	.48	.42	.034	4.16	87.62	12.38	8.22	5.32	27.41	31.76	226.2	....	33.05	135
	25	1.0314	.50	.41	.026	3.76	87.29	12.71	8.95	5.49	27.18	29.01	230.3	....	33.65	163
May	2	1.0327	.49	.42	.046	3.76	87.33	12.67	8.91	5.22	25.27	31.57	228.7	....	33.65	159
	9	1.0325	.52	.43	.036	4.07	87.21	12.79	8.72	4.48	25.72	29.83	227.9	....	33.85	145
	16	1.0329	.51	.42	.035	3.55	87.14	12.86	9.31	5.00	25.34	31.25	231.9	....	33.95	118
	23	1.0315	.52	.44	.037	3.84	87.84	12.16	8.32	4.70	......	......	......	....	......	137
	30	1.0313	.55	.47	.030	3.61	87.91	12.09	8.48	4.88	24.11	33.81	227.2	....	32.69	153
June	6	1.0325	.54	.45	.030	3.67	87.16	12.84	9.17	4.82	23.80	32.87	226.2	....	33.35	176
	13	1.0312	.53	.45	.034	3.71	87.66	12.34	8.63	4.62	24.79	32.37	224.8	....	34.45	134
	20	1.0305	.53	.41	.049	3.73	89.18	10.82	7.09	4.83	23.37	35.74	223.9	....	33.25	111
	27	1.0308	.53	.42	.043	3.46	88.07	11.93	8.47	4.70	24.67	36.33	225.6	....	33.00	91
July	4	1.0316	.51	.44	.016	3.42	87.96	12.04	8.62	5.35	24.59	35.98	222.8	....	31.68	121
	11	1.0303	.51	.42	.028	3.34	88.10	11.90	8.56	4.63	23.84	37.56	223.9	....	32.55	98
	18	1.0298	.52	.47	.047	4.51	86.76	13.24	8.73	5.26	21.83	40.91	227.1	....	33.13	124
	25	1.0273	.59	.52	.028	6.83	84.21	15.79	8.96	4.90	13.53	49.44	206.6	....	36.23	212
Aug.	1	1.0280	.49	.44	.029	4.99	86.75	13.25	8.26	4.77	13.14	48.51	207.3	....	35.50	151
	8	1.0302	.54	.48	.031	3.96	87.29	12.71	8.75	4.94	18.46	44.01	215.9	....	32.75	86
	15	1.0315	.57	.51	.028	4.01	86.90	13.10	9.09	5.02	23.55	40.16	217.9	....	34.15	103
	22	1.0330	.55	.53	.017	3.87	86.93	13.07	9.20	5.04	19.06	38.28	217.4	....	32.80	87
	29	1.0323	.61	.55	.021	3.99	86.73	13.27	9.28	5.16	25.79	36.04	223.5	....	......	95
Sept.	5	1.0340	.62	.57	.025	3.76	86.95	13.05	9.29	5.34	22.26	36.48	225.6	....	32.90	93
	12	1.0333	.65	.55	.039	4.30	86.26	13.74	9.44	5.15	21.17	37.56	218.7	....	33.26	123
	19	1.0375	.69	.60	.033	4.48	86.08	13.02	8.54	4.90	18.58	36.35	219.5	....	33.68	115

TABLE I.—*Analysis of the milk of each cow, by 7-day periods*—Continued.

COW NO. 400.

Week ending—	Specific gravity of milk.	Total nitrogen.	Casein nitrogen.	Albumin nitrogen.	Fat.	Water.	Total solids.	Solids not fat.	Sugar.	Reichert-Meissl number.	Iodin number.	Saponification number.	Refractive index.	Melting point.	Relative size of globules.
1907.		*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*					*°C.*	
Oct. 12	1.0345	0.57	0.47	0.069	4.48	85.84	14.16	9.68	5.64	30.89	30.37	230.1	1.4563	34.07	390
19	1.0355	.54	.45	.056	4.07	86.17	13.83	9.76	5.15	29.43	28.40	233.1	....	34.70	307
26	1.0360	.53	.45	.047	3.88	86.49	13.51	9.63	5.30	31.84	31.63	233.5	1.4573	33.50	557
Nov. 2	1.0360	.53	.42	.046	4.03	86.65	13.35	9.32	5.50	30.91	......	232.3	....	33.35	513
9	1.0340	.51	.41	.053	4.33	86.42	13.58	9.25	4.28	31.57	31.12	236.2	1.4566	33.40	567
16	1.0313	.52	.43	.061	3.95	86.75	13.25	9.30	5.17	31.64	31.93	233.6	1.4566	32.45	485
23	1.0337	.52	.42	.050	3.92	87.02	12.98	9.06	5.06	27.75	30.80	230.6	1.4570	33.50	332
30	1.0336	.50	.39	.047	4.17	86.65	13.35	9.18	5.74	26.26	34.61	226.4	1.4576	32.62	967
Dec. 7	1.0330	.48	.39	.014	4.13	86.42	13.58	9.45	5.47	25.82	41.04	222.8	1.4583	30.75	340
14	1.0325	.47	.38	.041	4.31	86.77	13.23	8.92	5.56	27.68	37.32	227.3	1.4586	31.45	305
21	1.0335	.44	.37	.047	3.99	87.13	12.87	8.88	5.40	24.80	37.91	225.9	1.4585	32.88	306
28	1.0340	.45	.37	.030	3.54	87.48	12.52	8.98	5.34	25.49	39.94	220.9	1.4569	31.35	318
1908.															
Jan. 4	1.0320	.45	.36	.039	3.30	87.95	12.05	8.75	5.01	25.41	29.97	236.8	1.4556	32.90	234
11	1.0330	.47	.38	.045	3.99	87.19	12.81	8.82	5.44	27.41	32.43	230.6	1.4562	33.65	283
18	1.0340	.49	.39	.039	3.57	87.89	12.11	8.54	5.04	23.68	31.65	227.6	1.4572	33.20	190
25	1.0328	.51	.40	.048	3.73	87.04	12.96	9.23	5.01	27.44	31.39	225.1	1.4558	32.83	274
Feb. 1	1.0331	.51	.42	.044	3.53	87.09	12.91	9.38	4.93	28.29	31.23	228.2	1.4552	32.85	232
8	1.0351	.52	.44	.062	3.92	86.72	13.28	9.36	4.74	29.07	31.89	228.8	1.4565	32.83	331
15	1.0340	.53	.44	.055	3.78	87.06	12.94	9.16	4.75	28.38	31.69	232.3	1.4555	32.75	240
22	1.0350	.56	.45	.020	3.55	86.89	13.11	9.56	5.04	28.56	31.83	228.3	1.4557	33.60	195
29	1.0346	.53	.45	.058	3.62	86.83	13.17	9.55	5.39	......	......	231.6	1.4561	......	330
Mar. 7	1.0334	.54	.43	.046	3.72	86.99	13.01	9.29	4.39	26.69	32.74	226.9	1.4575	33.75	173
14	1.0337	.55	.44	.030	3.61	86.99	13.01	9.40	4.58	26.12	34.70	224.1	....	34.20	450
21	1.0343	.55	.44	.038	3.79	87.00	13.00	9.21	5.45	26.80	32.50	226.0	....	33.68	156
28	1.0350	.55	.47	.057	3.52	87.31	12.69	9.17	5.28	24.92	34.05	226.5	....	34.00	269
Apr. 4	1.0340	.55	.45	.064	4.07	87.01	12.99	8.92	4.75	26.09	33.43	222.5	....	33.80	217
11	1.0340	.58	.43	.063	3.85	86.82	13.18	9.33	4.87	23.40	37.30	223.0	....	33.60	236
18	1.0332	.55	.44	.042	3.95	87.03	12.97	9.02	5.30	24.37	38.04	223.6	....	33.10	202
25	1.0337	.56	.45	.037	3.53	87.12	12.88	9.35	5.44	25.41	33.11	225.1	....	33.55	162
May 2	1.0344	.55	.45	.052	3.90	86.74	13.26	9.36	5.14	29.83	33.92	225.0	....	34.10	236
9	1.0346	.56	.47	.050	3.96	86.66	13.34	9.38	5.09	24.13	33.30	227.5	....	34.38	186
16	1.0347	.55	.48	.045	3.53	87.15	12.85	9.32	5.10	24.59	32.66	228.2	....	34.48	202
23	1.0326	.55	.43	.048	3.43	87.60	12.40	8.97	4.68	23.17	34.64	225.5	....	33.50	225
30	1.0320	.59	.46	.045	3.91	86.97	13.03	9.12	4.55	25.12	33.46	226.3	....	33.90	203
June 6	1.0340	.60	.46	.044	4.52	86.52	13.48	8.96	4.54	24.81	33.17	225.1	....	34.06	281
13	1.0328	.59	.46	.046	4.35	86.80	13.20	8.85	4.82	24.73	35.84	222.5	....	35.38	146
20	1.0310	.59	.46	.051	3.87	88.31	11.69	7.82	4.46	23.33	36.28	220.3	....	35.85	171
27	1.0300	.60	.48	.049	4.78	87.32	12.68	7.90	3.80	22.69	35.64	224.0	....	36.65	209
July 4	1.0307	.61	.50	.028	4.06	87.35	12.65	8.59	4.24	23.01	37.86	218.2	....	36.55	179
11	1.0300	.58	.49	.022	3.91	87.30	12.70	8.79	4.39	21.24	37.86	219.6	....	36.55	158
18	1.0290	.61	.55	.028	4.28	87.05	12.95	8.67	3.90	22.00	38.27	216.1	....	37.00	194
25	1.0300	.59	.51	.031	4.03	87.21	12.79	8.76	4.56	22.35	38.44	217.9	....	35.88	194
Aug. 1	1.0303	.58	.54	.021	4.20	87.21	12.79	8.59	4.29	22.41	38.77	216.5	....	36.60	194

TABLE I.—*Analysis of the milk of each cow, by 7-day periods*—Continued.

COW NO. 402.

Week ending—		Specific gravity of milk.	Total nitrogen.	Casein nitrogen.	Albumin nitrogen.	Fat.	Water.	Total solids.	Solids not fat.	Sugar.	Reichert-Meissl number.	Iodin number.	Saponification number.	Refractive index.	Melting point.	Relative size of globules.
1907.			*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*					°*C.*	
Oct.	26	1.0360	0.58	0.48	0.054	4.49	85.94	14.06	9.57	5.08	31.42	35.18	232.3	1.4573	32.87	536
Nov.	2	1.0350	.51	.43	.051	5.14	85.68	14.32	9.18	4.60	28.89	30.73	233.1	....	33.30	686
	9	1.0329	.51	.12	.051	4.48	86.38	13.62	9.14	4.73	30.89	29.36	235.2	1.4559	32.27	521
	16	1.0326	.52	.42	.047	4.08	87.06	12.94	8.86	4.68	31.69	27.77	236.4	1.4574	32.32	519
	23	1.0328	.50	.42	.045	4.31	86.82	13.18	8.87	4.56	26.81	28.56	236.2	1.4566	33.55	524
	30	1.0330	.52	.43	.049	4.20	86.66	13.34	9.14	5.45	27.00	27.57	236.2	1.4563	32.25	944
Dec.	7	1.0345	.53	.44	.060	4.20	86.59	13.41	9.21	5.85	25.68	30.72	230.9	1.4570	32.80	405
	14	1.0040	.52	.42	.041	3.96	86.77	13.23	9.27	5.40	29.05	30.00	232.2	1.4566	32.55	371
	21	1.0340	.51	.42	.048	4.21	86.54	13.46	9.25	4.86	27.58	29.34	233.7	1.4563	33.95	424
	28	1.0335	.49	.41	.041	3.92	87.09	12.91	8.99	5.18	27.22	30.15	232.8	1.4564	32.73	460
1908.																
Jan.	4	1.0325	.53	.42	.048	3.77	87.17	12.83	9.06	5.09	26.83	34.47	222.3	1.4560	32.85	339
	11	1.0340	.52	.42	.049	3.99	86.93	13.07	9.08	5.24	15.12	30.64	230.5	1.4554	33.25	354
	18	1.0337	.54	.43	.042	3.61	87.22	12.78	9.17	4.89	27.29	29.49	228.9	1.4555	33.27	312
	25	1.0340	.53	.44	.043	4.03	86.59	13.41	9.38	4.94	25.19	29.40	230.1	1.4558	32.95	275
Feb.	1	1.0344	.53	.43	.043	3.69	86.99	13.01	9.32	4.89	25.44	30.70	204.4	1.4569	32.75	272
	8	1.0340	.56	.45	.056	3.86	86.94	13.06	9.20	4.14	24.47	32.08	228.5	1.4558	33.40	235
	15	1.0330	.53	.44	.056	3.92	86.94	13.06	9.14	5.00	......	32.37	227.3	......	33.00	318
	22	1.0340	.56	.46	.051	3.84	86.74	13.26	9.42	4.75	26.10	31.61	228.9	1.4562	32.80	277
	29	1.0344	.54	.46	.041	3.80	86.79	13.21	9.41	4.05	26.85	31.67	228.9	1.4566	......	264
Mar.	7	1.0334	.55	.44	.030	3.80	86.89	13.11	9.31	4.40	25.25	32.68	228.1	1.4576	33.05	262
	14	1.0337	.56	.44	.041	3.79	86.85	13.15	9.36	5.33	24.29	35.25	222.8	....	33.80	253
	21	1.0340	.55	.44	.036	3.93	87.06	12.94	9.01	5.12	25.58	......	223.6	....	34.18	173
	28	1.0344	.55	.45	.060	3.78	87.14	12.86	9.08	5.13	23.53	35.39	225.2	....	33.73	317
Apr.	4	1.0336	.55	.44	.044	4.16	87.06	12.94	8.78	4.77	23.08	34.33	225.7	....	34.25	184
	11	1.0327	.54	.46	.047	3.94	86.90	13.10	9.16	5.35	22.37	38.15	221.0	....	34.18	277
	18	1.0327	.54	.44	.034	4.12	87.31	12.69	8.57	5.29	22.99	34.67	224.1	....	33.45	325
	25	1.0334	.56	.44	.047	3.76	86.98	13.02	9.26	5.20	25.79	33.18	225.4	....	33.90	279
May	2	1.0345	.55	.46	.041	4.09	86.74	13.26	9.17	5.33	23.84	34.53	224.4	....	33.50	204
	9	1.0340	.56	.45	.036	4.20	86.54	13.46	9.26	4.85	23.54	33.75	225.3	....	33.75	210
	16	1.0340	.55	.45	.044	3.78	87.32	12.68	8.90	......	22.38	35.63	221.8	....	34.80	175
	23	1.0325	.55	.46	.042	3.79	87.25	12.75	8.96	4.60	23.15	35.51	223.3	....	33.45	193
	30	....	.61	.44	.047	3.82	87.16	12.84	9.02	......	22.65	37.00	220.2	....	33.15	278
June	6	1.0330	.61	.49	.048	4.51	86.70	13.30	8.79	4.72	21.85	37.11	221.2	....	34.45	267
	13	1.0330	.58	.49	.053	4.55	86.28	13.72	9.17	4.78	18.42	41.33	214.4	....	34.50	185
	20	1.0330	.64	.53	.062	4.71	86.36	13.64	8.93	4.64	15.38	43.59	213.8	....	34.50	184
	27	1.0336	.70	.60	.057	4.92	85.44	14.56	9.64	4.31	17.92	42.02	213.8	....	35.15	215
July	4	1.0340	.69	.41	.025	4.75	85.63	14.37	9.62	4.29	17.22	42.98	211.7	....	35.48	227
	11	1.0325	.69	.61	.019	4.01	86.27	13.73	9.72	4.49	17.64	42.25	212.4	....	36.40	142
	18	1.0314	.71	.65	.044	4.50	86.27	13.73	9.23	4.14	14.98	41.33	210.4	....	37.05	210

TABLE I.—*Analysis of the milk of each cow, by 7-day periods*—Continued.

COW NO. 403.

Week ending—		Specific gravity of milk.	Total nitrogen.	Casein nitrogen.	Albumin nitrogen.	Fat.	Water.	Total solids.	Solids not fat.	Sugar.	Reichert-Meissl number.	Iodin number.	Saponification number.	Refractive index.	Melting point.	Relative size of globules.
1908.			P.ct.	P.ct.	P.ct.	P.ct.	P.ct.	P.ct.	P.ct.	P.ct.					°C.	
Feb.	22	1.0358	0.57	0.46	0.072	4.06	86.37	13.63	9.57	4.84	31.84	36.04	227.6	1.4564	32.80	415
	29	1.0360	.51	.43	.046	3.53	87.15	12.85	9.32	5.21	29.22	33.37	229.6	....	32.80	189
Mar.	7	1.0338	.51	.39	.058	3.45	87.58	12.42	8.97	5.27	27.49	29.79	252.3	1.4573	31.85	502
	14	1.0334	.50	.38	.036	3.27	87.51	12.49	9.22	5.52	28.87	34.13	227.6	....	33.35	823
	21	1.0333	.51	.37	.034	3.35	87.79	12.21	8.86	5.78	27.11	32.77	227.1	....	32.88	217
	28	1.0327	.48	.37	.063	3.35	87.93	12.07	8.72	5.28	28.52	33.01	229.5	....	33.25	352
Apr.	4	1.0333	.49	.39	.059	3.45	87.88	12.12	8.67	4.98	26.78	34.56	225.6	....	33.65	285
	11	1.0320	.46	.38	.047	3.36	87.78	12.22	8.86	4.83	24.26	40.36	219.3	....	33.50	359
	18	1.0320	.48	.36	.053	3.33	88.39	11.61	8.28	5.63	25.99	35.80	226.2	....	31.45	226
	25	1.0323	.46	.35	.029	2.96	88.14	11.86	8.90	5.33	27.47	31.47	230.4	....	32.68	188
May	2	1.0329	.46	.35	.040	3.16	88.47	11.53	8.37	5.58	26.10	32.31	227.1	....	33.00	229
	9	1.0336	.46	.38	.048	3.26	88.00	12.00	8.74	5.00	25.69	33.16	228.6	....	33.68	208
	16	1.0323	.47	.36	.045	3.01	88.68	11.32	8.31	5.29	26.54	32.90	232.8	....	32.90	147
	23	1.0316	.47	.37	.051	3.19	88.60	11.40	8.21	4.65	25.51	34.09	228.0	....	32.20	204
	30	1.0307	.47	.38	.035	3.00	88.48	11.52	8.52	4.93	25.72	33.45	230.0	....	32.30	186
June	6	1.0320	.48	.37	.043	3.45	87.99	12.01	8.56	5.12	27.43	34.54	228.6	....	33.00	194
	13	1.0310	.50	.37	.036	3.30	88.19	11.81	8.51	4.63	26.21	34.90	227.1	....	32.90	130
	20	1.0310	.49	.38	.042	3.16	88.44	11.56	8.40	4.70	24.43	35.20	225.9	....	32.90	120
	27	1.0323	.49	.31	.067	3.19	88.59	11.41	8.22	4.26	26.57	35.84	226.9	....	33.25	161
July	4	1.0315	.49	.41	.035	2.92	88.53	11.47	8.55	4.73	25.55	35.16	225.6	....	33.55	125
	11	1.0316	.50	.42	.019	3.07	88.25	11.75	8.68	5.03	......	......	......	....	33.13	117
	18	1.0310	.50	.44	.035	3.25	88.35	11.65	8.40	5.13	24.10	36.59	224.0	....	33.30	147
	25	1.0310	.51	.44	.036	3.19	88.41	11.59	8.40	5.11	26.64	35.80	239.7	....	33.20	129
Aug.	1	1.0315	.51	.43	.040	2.99	88.41	11.59	8.60	5.36	27.33	34.31	226.6	....	32.30	169
	8	1.0320	.53	.46	.032	2.57	88.60	11.40	8.83	5.13	25.12	35.72	224.0	....	32.70	120
	15	1.0318	.53	.46	.033	3.01	88.24	11.76	8.75	4.53	26.44	33.99	225.4	....	33.20	127
	22	1.0320	.53	.45	.026	4.02	84.23	15.77	11.75	5.08	27.19	34.66	225.1	....	32.20	205
	29	1.0326	.53	.46	.028	3.33	87.85	12.15	8.82	5.16	26.75	35.45	223.7	....	32.05	133
Sept.	5	1.0320	.55	.46	.065	3.30	87.82	12.18	8.88	5.33	25.32	35.36	225.5	....	32.55	143
	12	1.0322	.56	.46	.053	3.61	87.39	12.61	9.00	5.20	25.46	35.72	227.1	....	32.33	142
	19	1.0357	.56	.45	.054	3.46	87.71	12.29	8.83	5.18	23.58	37.16	224.2	....	32.55	129
	26	1.0333	.60	.50	.038	3.83	86.99	13.01	9.18	4.72	23.76	37.13	223.5	....	33.15	172
Oct.	3	1.0343	.61	.48	.070	3.80	87.01	12.99	9.19	4.54	......	......	......	....	32.68	167
	10	1.0333	.60	.51	.052	3.75	87.18	12.82	9.07	4.85	......	......	......	....	......	179
	17	1.0325	.49	.39	.050	3.88	89.12	10.88	7.00	2.85	......	......	......	....	......	250
	24	1.0333	.61	.44	.095	3.98	87.16	12.84	8.86	......	23.27	37.32	223.8	....	33.60	214
	31	1.0333	.58	.46	.105	4.26	86.78	13.22	8.96	3.88	23.59	35.42	224.9	....	33.70	190
Nov.	7	1.0290	.61	.45	.088	3.87	87.49	12.51	8.64	......	24.07	35.06	228.2	....	32.85	....
	14	1.0331	.61	.45	.098	3.92	87.08	12.92	9.00	4.23	24.43	35.54	225.2	....	33.35	142
	21	1.0330	.60	.44	.081	3.95	87.06	12.94	8.99	4.40	24.89	34.94	227.3	....	33.20	193
	28	1.0325	.61	.46	.110	3.94	87.17	12.83	8.89	4.34	25.65	35.33	229.0	....	32.65	160
Dec.	5	1.0329	.64	.47	.087	4.21	86.50	13.50	9.29	4.55	25.20	35.93	224.6	....	32.95	98
	12	....	.65	.48	.081	3.93	86.87	13.13	9.20	4.59	25.36	34.03	226.5	....	32.65	146
	19	....	.64	.49	.091	4.10	86.69	13.31	9.21	4.40	25.84	34.88	226.2	....	33.05	106
	26	....	......	......	......	......	......	......	......	......	23.03	35.88	224.9	....	33.30	....

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U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ANIMAL INDUSTRY.—BULLETIN 156.
A. D. MELVIN, CHIEF OF BUREAU.

THE INFLUENCE OF BREED AND INDIVIDUALITY ON THE COMPOSITION AND PROPERTIES OF MILK.

BY

C. H. ECKLES,
Professor of Dairy Husbandry, University of Missouri,

AND

ROSCOE H. SHAW,
Chemist, Dairy Division, Bureau of Animal Industry.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Animal Industry,
Washington, D. C., July 11, 1912.

Sir: I have the honor to transmit, and to recommend for publication in the bulletin series of this bureau, the accompanying manuscript entitled "The Influence of Breed and Individuality on the Composition and Properties of Milk," by Messrs. C. H. Eckles, professor of dairy husbandry, University of Missouri, and Roscoe H. Shaw, chemist in the Dairy Division of this bureau.

The experimental work reported herein forms part of a series of cooperative investigations inaugurated in 1906 between the Dairy Division and the Missouri Agricultural Experiment Station, with the object of studying in detail the factors influencing the composition and properties of milk as produced under normal dairy conditions. The first results of the work have been forwarded for publication as Bulletin 155, entitled "The Influence of the Stage of Lactation upon the Composition and Properties of Milk."

Respectfully,

A. D. Melvin,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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Fig. 1. Relative size of the fat globules in milk of dairy cattle.. 20

THE INFLUENCE OF BREED AND INDIVIDUALITY ON THE COMPOSITION AND PROPERTIES OF MILK.

INTRODUCTION.

In 1906 the Dairy Division of the Bureau of Animal Industry, in cooperation with the Missouri Agricultural Experiment Station, began a series of investigations, the main object of which was to study in detail the factors influencing the composition and properties of normal milk. It is a well-known fact that although the same constituents are always present in milk, the relative amount of each is subject to constant variations. Among the causes of these variations are known to be the breed of the animal, the stage of lactation, the individuality, and to some extent the feed, the interval between the milkings, and the temperature and weather conditions. It is also known that the first and the last milk drawn differ in composition.

A large amount of data has been published regarding these variations, the greater part of which deals with the fat content alone. In planning this series of investigations it was arranged to give attention first of all to the variations occurring during the period of lactation. The data concerning this part of the subject have been prepared for publication as Bulletin 155 of the Bureau of Animal Industry, entitled "The Influence of the Stage of Lactation on the Composition and Properties of Milk." In carrying on this investigation the plans were so arranged that the influence of breed and individuality of the animals could be studied concurrently with that of the period of lactation, and a presentation of these results is the object of the present paper.

There is no lack of data concerning the influence of the breed and the individuality of the animal upon the composition of milk as far as the per cent of the fat is concerned, although in practically all investigations reported there was no uniformity in the rations fed the animals and no data taken concerning the composition of the fat produced. When the influence of the stage of lactation is not taken into account, and when the ration is changed from time to time or varies with different animals, it is clearly impossible to state to what extent any variation found may be due to the ration fed and to what extent to the stage of lactation, breed, or individuality of the animal. It is especially important to keep the ration uniform, since it has been demonstrated that the nature of the food has an important influence, more particularly in regard to the composition of the fat.

PLAN OF THE INVESTIGATION.

Eleven animals were selected for the investigation, consisting of 3 representatives each of the Jersey, Holstein, and Shorthorn breeds, and 2 of the Ayrshire breed. These cows were typical specimens of the breed—that is to say, neither superior nor inferior producers of milk, but about the average. They were all purebred and registered. They were kept under much the same conditions as would be found in a commercial dairy except in regard to the control of the feed of the animals. The ration fed was of uniform composition throughout the entire lactation period and was made up as follows:

Choice alfalfa hay	3 parts.
Grain mixture:	
Corn, 8 parts	2 parts.
Bran, 1 part	
Oats, 1 part	

This ration supplied the nutrients necessary for milk production in about the right proportion. The ratio between the hay and the grain was such that the animals would eat the entire ration at all times. The amount fed was governed by the needs of the animal. The animals all went through the entire lactation period with no ill effects resulting from the lack of variety, and in no case was there any serious sickness of any kind. The hay, which was the most variable part of the ration, was bought in large quantities from the same source in order that there might be few changes in its composition. The animals were housed at night in the barn for feeding and milking and in the daytime were turned outside in a dry lot. The date for beginning the taking of samples was 5 days after the birth of the calf. The sampling was continued until the production of milk declined to the point where in a commercial dairy the cow would not be milked longer. A more detailed account of the plan of the investigation is found in Bulletin 155, previously mentioned.

METHOD OF SAMPLING AND PREPARATION OF SAMPLES FOR ANALYSIS.

The milk was weighed immediately after milking and mixed by pouring from one pail to another. A sample consisting of about 1 liter placed in a glass jar bearing the number of the cow and marked with the amount of milk produced was delivered at the laboratory. A certain number of cubic centimeters per pound of milk produced was then measured out and placed in a closed receptacle. In this manner a composite sample was prepared representing the production of that particular cow for 1 week. The milk was preserved by the addition of formalin. At the end of the week the composite sample was thoroughly mixed and a subsample consisting of about 300 c. c. taken for analysis. The remainder of the composite sample was heated to the proper temperature and the cream separated with a hand-power separator. The cream so obtained was churned by shaking in a glass jar, and the butter resulting was melted on a steam bath. The methods of sampling and analysis have been described in detail in Bulletin 155; it is sufficient to say that the methods of analysis followed were those of the Association of Official Agricultural Chemists wherever possible.

THE TRUE AVERAGE PER CENT.

In many cases in reporting analyses of milk a simple average instead of a true average is given. An average made in this manner is often misleading. In the case of the constituents of the milk it generally gives a result somewhat high, since milk becomes richer as it decreases in amount toward the end of the lactation period. Unless otherwise stated the averages given in this publication represent true averages. The average per cent of fat for the lactation period, for example, is found by dividing the total milk into the total fat produced.

RESULTS OF THE EXPERIMENTS.

Table 1 gives the data concerning the cows used in this investigation. Under the heading "Period samples were taken" is shown the periods covered by the samples taken for analysis.

TABLE 1.—*Data concerning the cows used.*

Breed.	No. of cow	Age.		Date of calving.	Date of breeding.	Period samples were taken.	Total yield of milk.	Average fat content.	Total yield of fat.
		Ys.	*mos.*				*Lbs.*	*P. ct.*	*Lbs.*
Jersey	4	6	10	Nov. 13, 1906	Dec. 30, 1906	Nov. 24, 1907, to Sept. 7, 1908	5,429	4.87	264.45
Do	99	8	1	Jan. 1, 1907	Mar. 23, 1907	Jan. 5, 1907, to Nov. 30, 1907	6,115	4.64	284.04
Do	118	11	4	Sept. 27, 1906	Not bred	Oct. 6, 1906, to Oct. 26, 1907	5,733	5.36	307.45
Ayrshire	300	3	8	Dec. 28, 1907	Feb. 23, 1908	Dec. 29, 1907, to Oct. 3, 1908	6,275	3.51	220.34
Do	301	4	8	Sept. 27, 1907	Mar. 16, 1908	Sept. 29, 1907, to Sept. 18, 1908	6,382	3.85	245.64
Holstein	205	5	3	July 17, 1907	Dec. 1, 1907	July 20, 1907, to Aug. 8, 1908	8,684	3.24	280.76
Do	206	5	0	May 31, 1907	Sept. 28, 1907	June 1, 1907, to Apr. 4, 1908	8,994	2.93	263.66
Do	209	3	8	July 20, 1907	Nov. 18, 1907	July 20, 1907, to July 4, 1908	8,814	3.02	273.34
Shorthorn	400	4	4	Sept. 30, 1907	Jan. 25, 1908	Oct. 5, 1907, to Aug. 1, 1908	5,172	3.89	201.37
Do	402	4	11	Oct. 13, 1907	Dec. 21, 1907	Oct. 19, 1907, to July 18, 1908	4,449	4.13	183.57
Do	403	6	0	Feb. 11, 1908	July 7, 1908	Feb. 15, 1908, to Dec. 19, 1908	6,539	3.35	220.52

TOTAL SOLIDS.

The determinations for total solids were made by using the Babcock asbestos method. The figures given are in each case an average of the determinations for 4 weekly composite samples. These are simple averages. The averages given for the lactation period of the animal and for the breeds are true averages.

Table 2 gives the percentage of total solids for each of the 11 animals used in the investigation by 4-week periods, the average for each animal for the period of lactation, and the average by breeds. The results correspond closely with those usually given for the breeds included. In Table 3 is given a compilation of analyses reported by several experiment stations in this country. The figures used include only those that represent purebred animals of the respective breeds, and where an entire period of lactation is involved. The data included in the column headed "Other American experiment stations" include all in print coming under the above conditions. A portion of this data was taken presumably by calculation from the specific gravity and the fat. Since these animals, owned by various experiment stations, represent a variety of conditions, it is believed that the average figure given, which includes all the data of such kind available up to the present, is reasonably accurate.

Table 4 gives the composition of the total solids in percentage of fat, protein, and sugar. The ash is not included, since it was lacking in some of the data, and furthermore, the amount of ash is so uniform with the different breeds and different individuals that no marked variations were found. The animals supplying the data from the New Jersey and New York experiment stations are the same as in Table 3.

TABLE 2.—*Average percentage of total solids for each cow, and breed average, by 4-week periods.*

Four-week period No.	Jerseys.				Ayrshires.		
	No. 4.	No. 99.	No. 118.	Average for Jerseys.	No. 300.	No. 301.	Average for Ayrshires.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
1	14.13			14.13	13.07	13.20	13.13
2		13.09	14.08	13.58	12.27	12.50	12.39
3		13.30	14.55	13.92	12.14	12.57	12.36
4	14.14	13.15		13.64	11.81	12.64	12.23
5	14.28	12.92		13.60	11.66	13.09	12.38
6	14.15	12.76	15.30	14.07	11.35	12.86	12.11
7	13.87	13.04	15.16	14.02	11.38	12.63	12.01
8	13.77	12.81	15.61	14.06	12.15	12.64	12.39
9	13.63	13.35	14.79	13.76	12.56	12.49	12.52
10	14.57	14.27	14.45	14.43	13.85	11.78	12.81
11		15.15	14.42	14.88		13.55	13.55
12		16.08	15.08	15.58		13.04	13.04
13			16.10	16.10		13.27	13.27
14			17.16	17.16			
True average of total solids.	14 09	13.34	15.02	14.09	12.08	12.71	12.41

TABLE 2.—*Average percentage of total solids for each cow, and breed average, by 4-week periods*—Continued.

Four-week period No.	Holsteins.				Shorthorns.			
	No. 205.	No. 206.	No. 209.	Average for Holsteins.	No. 400.	No. 402.	No. 403.	Average for Shorthorns.
	Per ct.	*Per ct.*	*Per ct.*	*Per cent.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per cent.*
1	11.74	10.95	11.24	11.31	13.71	13.74	12.85	13.43
2	11.58	10.10	10.23	10.64	13.29	13.29	12.16	12.91
3	11.70	10.18	10.63	10.84	13.05	13.07	11.75	12.62
4	11.95	10.27	11.07	11.10	12.48	13.07	11.56	12.37
5	12.11	10.54	11.15	11.27	13.06	13.16	11.56	12.59
6	11.77	10.73	10.96	11.15	13.05	12.97	11.65	13.56
7	11.98	10.75	11.20	11.31	12.96	13.02	12.77	12.92
8	12.16	10.80	11.23	11.39	13.08	12.93	12.52	12.84
9	11.95	11.01	11.58	11.51	13.03	13.81	12.38	13.07
10	12.12	11.90	12.58	12.20	12.43	13.94	12.90	13.09
11	12.20	13.30	12.99	12.83	12.84	....	13.19	13.02
12	12.50	....	13.51	13.01	....	....	....	....
13	13.04	....	14.52	13.78	....	....	....	....
14	13.42	....	....	13.42	....	....	....	....
True average of total solids.	12.12	10.73	11.35	11.38	13.08	13.01	12.17	12.69

TABLE 3.—*Comparison of total solids in this investigation with results reported by American experiment stations.*

Breed.	This investigation.		New Jersey Experiment Station.[1]		New York Experiment Station.[2]		Other American experiment stations.		General average.	
	Number of animals.	Average total solids.	Number of animals.	Average total solids.	Number of animals.	Average total solids.	Number of animals.	Average total solids.	Number of animals.	Average total solids.
		Per cent.		*Per cent.*		*Per cent.*		*Per cent.*		*Per cent.*
Jerseys	3	14.09	3	14.34	3	15.5	29	14.90	38	14.70
Guernseys	....	....	3	14.48	2	14.8	6	14.20	11	14.49
Ayrshire	2	12.41	3	12.70	4	12.8	17	12.98	26	12.72
Holstein	3	11.38	3	12.12	2	12.2	9	12.29	17	12.00
Shorthorns	3	12.69	3	12.45	....	....	....	....	6	12.57

[1] Neilson, James. Experiments with different breeds of dairy cows. New Jersey Agricultural Experiment Station, Bulletin 77. New Brunswick, Dec., 1890.

[2] New York Agricultural Experiment Station, Tenth, Eleventh, and Twelfth Annual Reports. Geneva, 1891, 1892, 1893.

TABLE 4.—*Average composition of the total solids in milk of dairy cattle, as reported by American experiment stations.*

Breed.	Fat.				Protein.				Sugar.			
	New Jersey.	New York.	Missouri.	Average.	New Jersey.	New York.	Missouri.	Average.	New Jersey.	New York.	Missouri.	Average.
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Jersey	33.3	36.4	35.1	34.9	27.6	25.4	25.8	26.3	33.8	33.4	34.5	33.9
Guernsey	34.7	35.1	......	34.9	27.1	24.7	......	25.9	33.3	35.0	......	34.2
Ayrshire	29.1	27.3	29.6	28.7	27.4	26.3	26.1	26.6	38.1	40.8	39.6	39.5
Holstein	29.1	28.0	27.1	28.1	27.1	27.4	28.1	27.5	38.7	39.1	37.3	38.4
Shorthorn	29.3	......	29.4	29.3	26.3	......	26.6	26.4	38.6	......	39.3	38.9

The fat represents from 28 to 35 per cent of the total solids, varying especially with the breed and to some extent with the individual. The total solids produced by the Jersey and Guernsey breeds contain, on an average, 34.9 per cent of fat, which is relatively high as compared with the Holstein, Ayrshire, or Shorthorn breeds. Among the breeds included in these data the Holstein, with an average of 28.1 per cent, has the lowest proportion of fat, while the Shorthorn ranks next. The rule is that those animals having a higher per cent of fat in the milk also have a relatively larger proportion of fat in the solids.

The individual animals show some variations, but on the whole they follow the characteristics of their breed quite closely. The per cent of fat in the total solids produced by the 3 Jerseys used in this investigation varied from 34.6 to 35.7, the 3 Holsteins from 26.7 to 27.3, while the 3 Shorthorns varied from 27.7 to 31.7. The individual variation has to be taken into account in connection with the total solids, but is of less importance than is the variation due to breed.

FAT.

Table 5 gives the percentage of fat in the milk of the 11 animals represented in the investigation, expressed in the same manner as the total solids. The well-known facts regarding the relative composition of the milk for the 4 breeds used is brought out in these data.

Table 6 gives the average percentage of fat in the milk of animals used in investigations at the New Jersey and New York experiment stations; also a compilation showing the average per cent of fat for all registered animals of the respective breeds, the records of which have been published by American experiment stations. This table includes only data relating to purebred animals and where it is possible to obtain a true average per cent of fat for the entire period of lactation. It is believed that the summary, representing as it does a large number of animals in different States under somewhat comparable conditions, gives a reliable average as to the fat content of the milk of the breeds represented.

TABLE 5.—*Average percentage of fat for each cow, and breed average, by 4-week periods.*

Four-week period No.	Jerseys.				Ayrshires.		
	No. 4.	No. 99.	No. 118.	Average for Jerseys.	No. 300.	No. 301.	Average for Ayrshires.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
1	5.17	5.22		5.20	4.01	3.87	3.97
2	4.63	4.79	5.31	4.91	3.61	3.74	3.68
3	5.07	4.43	5.55	5.02	3.38	3.81	3.60
4	4.85	4.40	5.11	4.79	3.36	3.81	3.59
5	4.81	4.33	5.51	4.88	3.32	4.08	3.70
6	5.00	4.22	5.71	4.98	3.26	3.78	3.52
7	4.73	4.36	5.69	4.93	3.30	3.95	3.63
8	4.51	4.18	5.80	4.83	3.53	3.94	3.74
9	4.73	4.63	5.17	4.84	3.74	3.67	3.71
10	5.18	4.98	4.47	4.88	4.52	3.58	4.05
11		5.62	4.83	5.23		4.92	4.92
12		6.07	5.28	5.68		3.96	3.96
13			5.48	5.48		4.18	4.18
14			6.47	6.47			
True average of total fat	4.87	4.64	5.36	4.95	3.51	3.85	3.68

TABLE 5.—*Average percentage of fat for each cow, and breed average, by 4-week periods*—Continued.

Four-week period No.	Holsteins.				Shorthorns.			
	No. 205.	No. 206.	No. 209.	Average for Holsteins.	No. 400.	No. 402.	No. 403.	Average for Shorthorns.
	P. ct.	*P. ct.*	*P. ct.*	*Per cent.*	*P. ct.*	*P. ct.*	*P. ct.*	*Per cent.*
1	3.24	3.07	3.12	3.14	4.12	4.55	3.58	4.08
2	3.14	2.88	2.60	2.87	4.09	4.17	3.38	3.88
3	3.02	2.58	2.74	2.78	3.99	3.97	3.18	3.71
4	3.25	2.84	3.24	3.11	3.65	3.80	3.16	3.54
5	3.29	2.89	3.14	3.11	3.70	3.84	3.14	3.56
6	3.06	3.06	2.81	2.96	3.69	3.92	3.13	3.58
7	3.26	2.88	2.94	3.03	3.85	3.98	3.23	3.69
8	3.25	3.00	3.01	3.09	3.73	3.90	3.55	3.73
9	3.15	3.00	3.01	3.05	4.05	4.67	3.85	4.19
10	3.31	3.09	3.52	3.31	4.16	4.42	4.00	4.19
11	3.31	3.40	3.46	3.39	4.17	....	4.05	4.11
12	3.49	....	3.90	3.69	....	....	....	....
13	3.68	....	5.28	4.48	....	....	....	....
14	3.68	....	....	3.68	....	....	....	....
True average of total fat	3.23	2.93	3.10	3.09	3.89	4.13	3.37	3.73

TABLE 6.—*Average percentage of fat in milk of dairy cattle, as reported by American experiment stations.*

Breed.	New Jersey.		New York.		Missouri.		All American experiment stations.	
	Number of animals.	Average fat.	Number of animals.	Average fat.	Number of animals.	Average fat.	Number of animals.	Average fat.
		Per cent.		*Per cent.*		*Per cent.*		*Per cent.*
Jersey	3	4.78	3	5.60	3	4.95	153	5.14
Guernsey	3	5.02	2	5.15	....	....	21	4.98
Ayrshire	3	3.68	4	3.57	2	3.68	24	3.85
Holstein	3	3.51	2	3.28	3	3.09	83	3.45
Shorthorn	3	3.65	....	....	3	3.73	40	3.63
Red Poll	....	....	....	....	....	....	9	4.03

It is a well-known fact that individuals within a breed vary considerably in the percentage of fat. The data here given are too limited to contribute much of value on this point. While by far the greater number of individuals within the breed will come close to the average for that breed, a comparatively few vary widely. It is characteristic of the breeds having the higher percentage of fat to show the greater individual variations. The percentage of fat secured during a lactation period may also be influenced to some extent by the time of the year in which the milking period began.[1] On the average the milk produced during the fall and early winter has a higher percentage of fat than that produced by the same animal in the early spring and summer. For this reason the cow that is fresh in the fall and produces the largest quantity of milk during the cool weather will have a higher average test for the year than will be the case if she freshens in the spring and produces the maximum yield during the period of warm weather.

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[1] Eckles, C. H. Jahreszeitliche Schwankungen des prozentischen Fettgehaltes in Kuhmilk. Milchwirtschaftliches Zentralblatt, vol. 5, no. 11, p. 488-502. Leipzig, Nov. 1909.

TOTAL PROTEIN.

Table 7 gives the percentage of total nitrogen as protein for each individual and the average for each breed. The totals are also calculated as protein by using the factor 6.38. The results show a decided influence due to the breed of the animals, the Jersey having a uniformly higher percentage of protein than the others. The Holsteins are the lowest, while the Shorthorns and Ayrshires range between the Holsteins and Jerseys. The marked influence exerted by the stage of lactation upon the proportion of this constitutent present can be seen from the data given and has been shown in a previous publication.[1]

Table 8 is a compilation from the same sources as used in previous tables showing the average percentage of protein in the milk of 5 breeds. It will be noted that the figures obtained at the Missouri Experiment Station for Holsteins, Jerseys, and Ayrshires are somewhat lower than those obtained at the New Jersey and New York stations, while the figure for the Shorthorns is slightly above. There is some variation with the individuals regarding the amount of this constituent secreted, as is the case with other constituents of the milk. The individuals and breeds having the higher percentage of fat have at the same time the higher percentage of protein. The same animals also have a higher ratio of fat to protein. With the 11 cows used in our investigation, for each pound of protein there was found in the milk of the Jerseys 1.36 pounds of fat, in the Ayrshires 1.13, in the Shorthorns 1.10, and in the Holsteins 1.05. While an individual or a breed that produces milk with a high percentage of fat is certain to have a high percentage of protein as well, the protein and the fat do not increase in the same proportion.

TABLE 7.—*Average total nitrogen for each cow, and breed average, by 4-week periods, and average total nitrogen and protein for the whole lactation period.*

Four-week period No.	Jerseys.				Ayrshires.		
	No. 4.	No. 99.	No. 118.	Average for Jerseys.	No. 300.	No. 301.	Average for Ayrshires.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
1	0.52	0.51	....	0.52	0.53	0.56	0.54
2	.53	.51	0.51	.52	.47	.50	.48
3	.57	.51	.56	.55	.48	.48	.48
4	.61	.49	.54	.55	.47	.51	.49
5	.60	.49	.65	.58	.46	.51	.49
6	.59	.49	.65	.58	.47	.53	.50
7	.59	.48	.67	.58	.46	.51	.49
8	.57	.50	.64	.57	.49	.50	.50
9	.62	.52	.64	.59	.57	.53	.55
10	.66	.56	.64	.62	.67	.53	.60
11	....	.62	.65	.63	....	.53	.53
12	....	.66	.70	.68	....	.57	.57
13	....	....	.75	.75	....	.65	.65
14	....	....	.77	.77	....	....	....
True average of total nitrogen	.58	.51	.62	.57	.49	.52	.51
True average of total protein	3.70	3.27	3.97	3.64	3.11	3.33	3.25

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[1] Bulletin 155, Bureau of Animal Industry, U. S. Department of Agriculture. Washington, 1912.

TABLE 7.—*Average total nitrogen for each cow, and breed average, by 4-week periods, and average total nitrogen and protein for the whole lactation period*—Continued.

Four-week period No.	Holsteins.				Shorthorns.			
	No. 205.	No. 206.	No. 209.	Average for Holsteins.	No. 400.	No. 402.	No. 403.	Averaget for Shotrhorns.
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
1	0.49	0.44	0.50	0.48	0.54	0.53	0.52	0.53
2	.43	.38	.45	.42	.51	.52	.49	.51
3	.44	.37	.45	.42	.46	.51	.47	.48
4	.44	.39	.47	.43	.48	.54	.47	.50
5	.45	.42	.45	.44	.53	.55	.49	.52
6	.45	.42	.46	.44	.54	.55	.51	.53
7	.45	.41	.50	.45	.56	.55	.53	.55
8	.44	.43	.49	.45	.56	.57	.57	.57
9	.48	.44	.52	.48	.58	.63	.58	.59
10	.48	.51	.60	.53	.60	.70	.60	.63
11	.51	.71	.65	.62	.59	....	.64	.61
12	.55	....	.73	.64	....	....	....	....
13	.59	....	.71	.65	....	....	....	....
14	.65	....	....	.65	....	....	....	....
True average of total nitrogen	.47	.42	.50	.46	.53	.55	.51	.53
True average of total protein	3.00	2.70	3.21	2.93	3.40	3.49	3.28	3.38

TABLE 8.—*Average percentage of total protein in milk of dairy cattle, as reported by American experiment stations.*

Breed.	New Jersey.		New York.		Missouri.		Average.	
	Number of animals.	Average protein.	Number of animals.	Average protein.	Number of animals.	Average protein.	Number of animals.	Average protein.
		Per cent.		*Per cent.*		*Per cent.*		*Per cent.*
Jersey	3	3.96	3	3.81	3	3.64	9	3.80
Guernsey	3	3.92	2	3.75	....	....	5	3.84
Ayrshire	3	3.48	4	3.29	2	3.25	9	3.34
Holstein	3	3.28	2	3.23	3	2.93	8	3.15
Shorthorn	3	3.27	....	....	3	3.38	6	3.32

CASEIN.

Table 9 gives the average percentage of protein in the form of casein for each individual and for each breed. Much the same range of variation is found here as is the case with the total protein. The percentage of the total protein present as casein was for the Holstein milk 80.4, the Jersey 80.7, the Ayrshire 83, and the Shorthorn 83.5. No special breed characteristics can be observed in regard to the relation of casein to the total protein. The individual variation is of some importance, but not so very much.

TABLE 9.—*Average casein nitrogen for each cow, and breed average, by 4-week periods, and average casein nitrogen and casein for the whole lactation period.*

Four-week period No.	Jerseys.				Ayrshires.		
	No. 4.	No. 99.	No. 118.	Average for Jerseys.	No. 300.	No. 301.	Average for Ayrshires.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
1	0.44	0.42	....	0.43	0.44	0.56	0.50
2	.38	.41	.32	.37	.40	.50	.45
3	.48	.40	.48	.45	.40	.48	.44
4	.49	.40	.42	.44	.38	.51	.45
5	.48	.40	.54	.47	.39	.51	.45
6	.48	.40	.52	.47	.39	.53	.46
7	.47	.39	.54	.47	.39	.51	.45
8	.46	.40	.54	.47	.44	.50	.47
9	.50	.42	.51	.48	.52	.53	.53
10	.52	.46	.50	.49	.59	.53	.56
11	....	.51	.51	.51	....	.53	.53
12	....	.53	.55	.54	....	.57	.57
13	....	....	.61	.61	....	.65	.65
14	....	....	.58	.58	....	....	....
True average of casein nitrogen	.46	.42	.49	.46	.41	.44	.42
True average of casein	2.93	2.65	3.13	2.93	2.62	2.81	2.70

Four-week period No.	Holsteins.				Shorthorns.			
	No. 205.	No. 206.	No. 209.	Average for Holsteins.	No. 400.	No. 402.	No. 403.	Average for Shorthorns.
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
1	0.40	0.34	0.39	0.38	0.45	0.44	0.42	0.44
2	.35	.30	.34	.33	.41	.43	.38	.41
3	.34	.29	.34	.32	.38	.42	.36	.39
4	.36	.30	.36	.34	.38	.44	.37	.39
5	.37	.32	.35	.35	.44	.45	.37	.42
6	.38	.33	.36	.36	.44	.44	.43	.44
7	.37	.31	.39	.36	.45	.45	.46	.45
8	.37	.33	.40	.37	.46	.45	.47	.46
9	.38	.36	.41	.38	.45	.53	.46	.48
10	.39	.42	.49	.43	.48	.56	.45	.49
11	.43	.58	.53	.51	.53	....	.48	.51
12	.45	....	.59	.52	....	....	....	....
13	.51	....	.58	.54	....	....	....	....
14	.57	....	....	.57	....	....	....	....
True average of casein nitrogen	.39	.33	.39	.37	.43	.45	.41	.43
True average of casein	2.49	2.11	2.49	2.36	2.74	2.87	2.62	2.74

RELATION OF THE CASEIN TO THE FAT.

The relation between the fat and the casein is of considerable interest on account of the possibility it affords of calculating the casein content from the fat analyses and its relation to methods of paying for milk of varying quality to be used for cheese making. Van Slyke[1] formulated a rule for estimating the casein, limited in its application to milk with fat contents between 3 and 4.5 per cent. Shuttleworth[2] showed that considerable variations occur with individual cows regarding the relation of fat to casein.

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[1] Van Slyke, Lucius L. Modern methods of testing milk and milk products. New York, 1907. See p. 192.

[2] Ontario Agricultural College and Experimental Farm, Twenty-first Annual Report (1895), pp. 19-27. Toronto, 1896.

Hart[1] studied the relation between the fat and the casein in the milk of 26 cows representing 5 breeds and covering 12 days' time. He finds that "the relation of casein to fat varies among animals of different breeds and among animals of the same breed." His data averaged by breeds are as follows:

Breed.	Relation of fat and casein.
Jersey	1.72 : 1
Guernsey	1.90 : 1
Holstein	1.49 : 1
Ayrshire	1.44 : 1

The following gives the relation of the fat to the casein in the milk of each of the 11 cows used in our investigation:

Breed.	No.	Ratio of fat to casein.
Jersey	4	1.66 : 1
Do	99	1.75 : 1
Do	118	1.71 : 1
Average for Jerseys		1.69 : 1
Ayrshire	300	1.20 : 1
Do	301	1.47 : 1
Average for Ayrshires		1.36 : 1
Holstein	205	1.30 : 1
Do	206	1.38 : 1
Do	209	1.25 : 1
Average for Holsteins		1.31 : 1
Shorthorn	400	1.35 : 1
Do	402	1.44 : 1
Do	403	1.29 : 1
Average for Shorthorns		1.36 : 1

The above statement, representing as it does in each case the entire lactation period of the animal fed a uniform ration, gives a fair basis from which to study this question. The figures show that there is a variation in the ratio between the fat and the casein that is dependent upon breed. There is little difference between the Holstein, Ayrshire, and Shorthorn breeds, but the Jersey shows a much wider ratio than the others. A study of the figures for the individual animals shows a reasonably close agreement within the breed. The conclusion from our data would be that while there is some variation with the individual the variation due to breed is of greater importance, and that the breeds that have the highest percentage of fat have the widest ratio between the fat and the casein.

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[1] Hart, E. B. Variations in the amount of casein in cow's milk. Journal of the American Chemical Society, vol. 30, No. 2, pp. 281-285. Easton, Pa., Feb., 1908.

SUGAR.

The sugar content was determined by the optical method.[1] The results are found in Table 10. This table shows that the percentage of sugar in the milk of the Jersey, Ayrshire, and Shorthorn breeds was practically the same, while that in the Holstein was somewhat lower.

Table 11 gives the average percentage of sugar from the same sources as previously used. The average figures show that the Holstein breed has a somewhat lower percentage of sugar than the other breeds, although the variation is small as compared with that of other constituents. It is a well-established fact that, with the exception of the ash, sugar is the least subject to variations of the milk constituents. Some variation, however, is found with the individuals. This is especially noticeable with the Holsteins, where one has an average of 5.05 per cent and another 4.25 per cent. The sugar composes from 34 to 39 per cent of the total solids, varying in this respect with the breed.

TABLE 10.—*Average percentage of sugar for each cow, and breed average, by 4-week periods.*

Four-week period No.	Jerseys.				Ayrshires.		
	No. 4.	No. 99.	No. 118.	Average for Jerseys.	No. 300.	No. 301.	Average for Ayrshires.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
1	4.89	4.94	....	4.92	5.14	5.17	5.16
2	4.99	5.15	4.47	4.87	4.81	4.72	4.77
3	4.87	5.17	4.70	4.91	4.64	5.62	5.13
4	5.28	5.06	4.56	4.97	4.87	5.16	5.02
5	5.12	5.04	4.83	4.99	4.96	4.77	4.87
6	5.00	4.50	5.21	4.90	4.57	4.43	4.50
7	4.39	4.52	5.20	4.70	4.82	5.38	5.10
8	4.45	5.14	5.40	4.99	5.08	5.13	5.11
9	4.67	4.62	4.57	4.62	5.13	4.85	4.99
10	4.60	5.03	4.73	4.79	4.39	4.88	4.64
11	....	5.02	4.90	4.96	....	4.89	4.89
12	....	5.61	4.72	5.17	....	5.04	5.04
13	....	....	4.46	4.46	....	5.13	5.13
14	....	....	5.22	5.22	....	....	....
True total average	4.85	4.95	4.80	4.87	4.85	4.96	4.90

Four-week period No.	Holsteins.				Shorthorns.			
	No. 205.	No. 206.	No. 209.	Average for Holsteins.	No. 400.	No. 402.	No. 403.	Average for Shorthorns.
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
1	4.69	4.07	4.40	4.39	5.40	4.77	5.21	5.13
2	4.98	4.49	4.00	4.49	5.06	5.32	5.22	5.20
3	4.84	4.44	4.17	4.48	5.44	5.09	5.39	5.31
4	5.18	4.12	3.95	4.42	5.13	4.72	5.00	4.95
5	5.42	4.26	4.42	4.70	4.87	4.55	4.58	4.67
6	5.37	4.04	4.36	4.59	4.95	5.09	5.16	5.07
7	5.20	4.74	4.16	4.70	5.05	5.29	4.98	5.11
8	4.76	4.25	3.94	4.32	5.19	4.73	5.11	5.01
9	5.10	4.09	4.43	4.54	4.65	4.61	4.08	4.45
10	5.12	3.94	4.62	4.56	4.22	4.31	4.17	4.23
11	5.13	4.50	4.79	4.81	4.25	....	....	4.25
12	5.02	....	4.15	4.64	....	....	....	....
13	4.89	....	4.30	4.60	....	....	....	....
14	4.81	....	....	4.81	....	....	....	....
True total average	5.05	4.26	4.25	4.51	5.04	4.91	4.98	4.99

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[1] Official and provisional methods of analysis. U. S. Department of Agriculture, Bureau of Chemistry, Bulletin 107 (revised). Washington, 1908. See p. 118.

TABLE 11.—*Average percentage of sugar in milk of dairy cattle, as reported by American experiment stations.*

Breed.	New Jersey.		New York.		Missouri.		Average.	
	Number of animals.	Average sugar.	Number of animals.	Average sugar.	Number of animals.	Average sugar.	Number of animals.	Average sugar.
		Per cent.		*Per cent.*		*Per cent.*		*Per cent.*
Jersey	3	4.85	3	5.41	3	4.87	9	5.04
Guernsey	3	4.80	2	5.16	....	....	5	4.98
Ayrshire	3	4.84	4	5.33	2	4.90	9	5.02
Holstein	3	4.69	2	5.02	3	4.25	6	4.65
Shorthorn	3	4.80	....	....	3	4.99	6	4.89

THE CHEMICAL AND PHYSICAL CONSTANTS OF THE FAT.

While the previously published data regarding the constituents of milk are extensive, little is in print concerning the chemical and physical constants of the fat as influenced by the breed and individuality of the animal, with the exception of the relative size of the fat globules. Veith[1] studied the milk of 3 breeds of cows and concluded that the breed does not have any appreciable influence upon the nature of the fat. Kirchner[2] states that the composition of the fat is dependent mostly upon the stage of lactation and the food of the animal, but also varies to some extent with the individual animal.

The object of the investigations herein reported, as far as the variations due to breed and individuality are concerned, was especially to gather data concerning the fat. Since the rations fed the animals was uniform in all cases, the variations found can reasonably be attributed to the influence of the breed or of the individual.

RELATIVE SIZE OF THE FAT GLOBULES.

The determination of the relative size of fat globules was introduced by Babcock.[3] A description of this method of measurement is also found in Bulletin 111, Bureau of Animal Industry, United States Department of Agriculture. The method is essentially one of comparing the average volumes. It has been observed by several investigators that the breed of the animal has a decided influence upon the size of the fat globules. Jones[4] found that the milk of the Holstein had a much larger proportion of small fat globules, while the Jersey and the Guernsey had the largest, the Ayrshire standing between. Woll[5] gives the following data concerning the size of the fat globules in the milk of the 3 breeds which were entered in competition at the Columbian Exposition at Chicago in 1893:

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[1] Vieth, P. Butterfett-Untersuchungen nach Reichert-Wollny's Methode. Milch Zeitung, vol. 18, no. 28, p. 541–545. Bremen, July 10, 1889.

[2] Kirchner, W. Handbuch der Milchwirtschaft. Berlin, 1898. See p. 16.

[3] New York Agricultural Experiment Station, Fourth Annual Report (1885), p. 293–302. Albany, 1886.

[4] Jones, L. R. Study of milk globules. Vermont Agricultural Experiment Station, Fourth Annual Report (1890), p. 65–69. Burlington, 1891.

[5] Woll, F. W. The fat globules in cows' milk. Wisconsin Agricultural Experiment Station, Eleventh Annual Report (1894), p. 223–239. Madison, 1895.

Breed.	Number of cows.	Relative size of globules.	Average diameter.
			Microns.
Jersey	25	290	3.95
Guernsey	25	217	3.58
Shorthorn	24	177	3.35

Gutzeit[1] gives the average diameter of the fat globules in his investigation as follows:

	Microns.
Jersey	3.50
Shorthorn	2.76
Holstein	2.58

Table 12 gives the relative size of the fat globules as determined for each of the 11 animals used in our investigation and the averages for the breeds. This table shows the same results as noted by others, the Jersey having by far the largest fat globules, while the Holstein have the smallest, the Shorthorn standing between the Holstein and the Jersey. The comparative size of the fat globules in the milk of these 4 breeds is illustrated graphically in figure 1. The chief difference between the size of the fat globules with the different breeds is that with the Jersey there is a greater proportion of the larger globules and that the milk of the other breeds contains a limited number as large as the largest in the Jersey milk. The milk of the Holstein breed is especially noticeable in containing a large number of small fat globules, together with a wide variation in size.

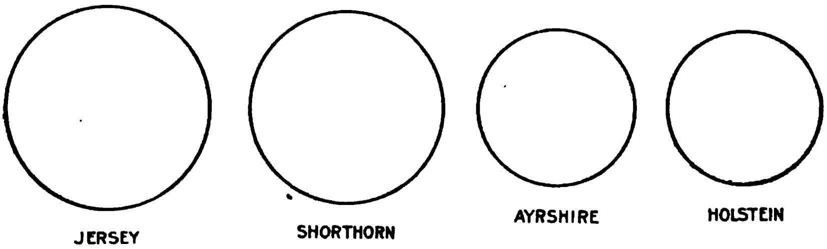

FIG. 1.—Relative size of the fat globules in the milk of dairy cattle.

The table shows that the individuality of the animal has some influence upon the size of the fat globules, but it is of less importance than the breed characteristic. The milk of an Ayrshire or a Holstein can be distinguished from that of a Jersey with considerable certainty by the characteristic of the fat globules alone. The Shorthorn, on the other hand, has fat globules that in many cases are as large as those contained in the milk of the Jersey, although less uniform in size.

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[1] Gutzeit, Ernst. Die Schwankungen der mittleren Grösse der Fettkügelchen in der Kuhmilch nach Laktation, Fütterung und Rasse, sowie über den physikalischen und chemischen Unterschied der grössten und kleinsten Fettkügelchen. Landwirthschaftliche Jahrbücher, vol. 24, p. 539-667. Berlin, 1895. See p. 648.

TABLE 12.—*Relative size of fat globules in milk of each cow, and breed average, by 4-week periods.*

Four week period No.	Jerseys.				Ayrshires.		
	No. 4.	No. 99.	No. 118.	Average for Jerseys.	No. 300.	No. 301.	Average for Ayrshires.
1	363	556	....	459	235	232	234
2	423	339	....	381	163	189	176
3	370	325	417	371	148	142	145
4	229	274	879	461	135	155	145
5	267	264	358	296	115	165	140
6	267	349	373	326	133	178	156
7	235	370	301	302	93	163	128
8	299	367	334	333	80	151	116
9	318	270	335	308	75	146	111
10	228	209	259	232	129	114	122
11	167	263	342	257	....	146	146
12	....	315	229	272	....	93	93
13	....	....	438	438	....	110	110
14	....	....	461	461	....	....	....
True average of relative size of globules	309	336	338	328	141	160	150

Four-week period No.	Holsteins.				Shorthorns.			
	No. 205.	No. 206.	No. 209.	Average for Holsteins.	No. 400.	No. 402.	No. 403.	Average for Shorthorns.
1	242	253	321	272	442	566	357	455
2	147	269	139	185	593	561	303	486
3	148	124	136	136	317	394	213	308
4	147	157	138	147	245	274	183	234
5	127	134	104	122	250	280	134	221
6	82	155	89	109	277	232	141	217
7	107	132	98	112	231	271	146	216
8	96	110	99	102	197	214	147	186
9	98	96	105	99	214	213	203	210
10	90	74	79	81	179	193	175	182
11	81	79	63	74	194	....	128	161
12	117	....	76	97	....	....	....	....
13	102	....	118	110	....	....	....	....
14	179	....	....	179	....	....	....	....
True average of relative size of globules	127	164	134	142	311	353	211	282

THE REICHERT-MEISSL NUMBER.[1]

The results for the Reichert-Meissl number are given in Table 13. The Holsteins show the lowest figure for the number, although the

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[1] This and the two succeeding constants of the fat were determined by official methods, the details of which may be found in Bulletin 107 (revised), Bureau of Chemistry, U. S. Department of Agriculture. For the benefit of those who may be unfamiliar with the terms the following explanation may be helpful: The Reichert-Meissl number is an arbitrary measure of the volatile acids of which butyric is the principal one in butterfat. The figures do not show the percentages of the acid, but serve as a means of comparing different fats with reference to their volatile constituents. The iodin absorption number indicates relatively the amount of iodin a fat will absorb. Since the only fatty acid found to exist in butterfat which has the property of absorbing iodin is oleic acid, the iodin absorption number shows relatively the amount of this fatty acid present, but in common with the Reichert-Meissl number the figures do not represent percentages. The saponification number is the number of milligrams of potassium hydroxid required to saponify 1 gram of fat. Since the amount of potassium hydroxid required depends upon the molecular weight of the fat the saponification number serves as an indicator of the relative percentages of the fatty acids of high and low molecular weights present.

Ayrshires on the average are only 0.5 higher, while the Shorthorns and the Jerseys show a somewhat higher figure. The individual variations are very marked in the case of Jersey No. 118 with an average of 23.28, which is the lowest of the entire number. If the data of this individual was not included the average for the Jersey would be considerably higher than any of the other breeds. With the exception of this individual there is no marked variation that is to be attributed to the individuality of the animal. The marked variation in the Reichert-Meissl number due to the advance in the period of lactation is evident from the table.

TABLE 13.—*Average Reichert-Meissl number for each cow, and breed average, by 4-week periods.*

Four-week period No.	Jerseys.				Ayrshires.		
	No. 4.	No. 99.	No. 118.	Average for Jerseys.	No. 300.	No. 301.	Average for Ayrshires.
1	29.22	30.16	29.54	29.64	27.66	30.59	29.13
2	28.72	28.88	23.28	26.96	28.96	27.09	28.03
3	28.52	32.09	24.14	28.25	27.76	26.58	27.17
4	28.50	30.95	23.69	27.71	25.76	25.13	25.45
5	28.96	27.67	23.90	26.84	26.83	24.88	25.86
6	29.20	31.21	24.64	28.35	25.76	26.79	26.28
7	26.87	27.03	26.66	26.83	24.57	25.59	25.08
8	28.63	27.54	23.12	29.76	23.87	26.40	25.29
9	25.24	27.03	25.04	25 77	23.09	24.42	23.76
10	25.95	25.83	22 85	24.88	17.96	24.36	21.16
11	....	24.73	22.79	23.76	....	18.09	18.09
12	....	18.43	20.22	19 33	....	21.72	21.72
13	....	....	14.23	14.23	....	20.67	20.67
14	....	....	14.21	14.21	....	....	....
True average of Reichert-Meissl number..........	28.17	28.69	23.28	26.73	26.34	25.52	25.93

Four-week period No.	Holsteins.				Shorthorns.			
	No. 205.	No. 206.	No. 209.	Average for Holsteins.	No. 400.	No. 402.	No. 403.	Average for Shorthorns.
1	26.66	30.15	25.65	27.49	30.77	30.72	29.36	30.28
2	26.01	29.48	26.84	27.44	29.31	27.14	26.67	27.71
3	26.33	28.15	25.10	26.53	25.95	26.69	26.31	26.32
4	27.38	24.58	27.05	26.34	25.99	25.60	26.30	25.96
5	27.82	27.19	24.82	26.61	28.58	26.07	25.69	26.78
6	26.92	24.51	24.68	25.37	26.54	24.12	26.02	25.56
7	28.05	24.28	22.79	25.04	24.70	23.75	26.38	24.94
8	27.53	23.39	23.47	24.80	25.99	22.93	24.53	24.48
9	27.86	23.53	24.23	25.21	24.46	18.39	23.27	22.04
10	26.06	20.76	20.17	22.33	22.57	16.61	24.25	21.14
11	25.63	17.62	21.32	21.52	22.25	....	25.51	23.88
12	20.39	....	20.70	20.55	....	....	....	....
13	12.77	....	21.14	16.96	....	....	....	....
14	10.27	....	....	10.27	....	....	....	....
True average of Reichert-Meissl number..........	25.81	26.13	24.44	25.46	26.89	25.55	26.29	26.28

THE IODIN ABSORPTION NUMBER.

Table 14 gives the data in regard to the iodin number for each individual and for the 4 breeds. It will be observed that with this constant there is an evident variation due to breed. The Shorthorn and the Holstein show a noticeably higher iodin number than the Jersey, while the Ayrshire comes between. The Jersey cow No. 118 shows an individual variation in this respect, as is the case with the Reichert-Meissl number. If the figures on this animal be left out of the total the variation with the breeds would be even more marked. The variation with the breeds, since it shows practically the same for each individual, seems sufficient to warrant the conclusion that there is a variation in this constant to be attributed to breed and that the Holstein and the Shorthorn may be expected to show the highest figures, while the Jersey is at the other extreme.

TABLE 14.—*Average iodin number for each cow, and breed average, by 4-week periods.*

Four-week period No.	Jerseys.				Ayrshires.		
	No. 4.	No. 99.	No. 118.	Average for Jerseys.	No. 300.	No. 301.	Average for Ayrshires.
1	31.08	32.68	39 31	34.36	32.58	28.58	30.53
2	28.04	29.46	36.33	31.28	28.70	29.91	29.31
3	29.61	28.96	32.54	30.37	27.69	30.56	29.13
4	29.94	26.75	28.69	28.46	31.91	29.85	30.88
5	28.84	29.99	31.55	30.13	27.50	30.93	29.22
6	28.03	27.29	30.43	28.58	29.61	30.31	29.96
7	31.46	27.93	28.67	29.35	35.30	31.04	33.17
8	29.75	27.37	32.49	29.87	37.32	30.54	33.93
9	32.27	28.71	33.67	31.55	35.23	32.64	33.94
10	32.15	28.80	31.43	30.79	37.74	35.11	36.43
11	....	27.61	31.14	29.38	....	44.11	44.11
12	....	29.55	32.37	30.96	....	39.62	39.62
13	....	....	38.48	38.48	....	36.80	36.80
14	....	....	35.82	35.82	....	....	....
True total average	29.99	28.87	32.79	30.52	31.14	32.06	31.61

Four-week period No.	Holsteins.				Shorthorns.			
	No. 205.	No. 206.	No. 209.	Average for Holsteins.	No. 400.	No. 402.	No. 403.	Average for Shorthorns.
1	37.12	31.00	39.46	35.86	30.13	30.76	33.33	31.42
2	34.54	30.57	33.32	32.81	32.12	39.21	35.18	35.50
3	33.23	35.53	32.89	33.88	39.05	31.15	33.19	34.46
4	31.85	31.70	33.10	32.22	31.36	30.42	33.75	31.84
5	31.77	31.79	33.53	32.36	31.66	32.08	35.28	33.01
6	32.64	31.67	34.91	33.07	33.31	35.16	35.57	34.68
7	32.62	33.14	36.62	34.13	35.71	35.13	34.96	35.26
8	33.45	34.25	35.59	34.43	33.25	35.47	36.34	35.02
9	34.07	33.91	37.01	35.00	34.28	41.01	37.32	37.54
10	35.56	35.27	39.08	36.63	36.91	42.19	35.24	38.11
11	35.40	36.53	35.35	35.76	38.49	....	35.04	36.77
12	37.53	....	36.69	37.11	....	....	....	....
13	42.57	....	39.03	40.80	....	....	....	....
14	42.24	....	....	42.24	....	....	....	....
True total average	34.46	32.68	35.48	34.20	34.08	34.09	34.72	34.36

THE SAPONIFICATION OR KOETTSTORFER NUMBER.

The data regarding this constant are found in Table 15. The variations that may be attributed to breed are comparatively small. The Holsteins show a number 1.5 higher than the Shorthorns. This difference, while comparatively small, seems to indicate at least some tendency for a variation between these two breeds. With this exception no special variation can be observed that may be attributed safely to the influence of the breed. No marked individual variations are observed, with the exception of Jersey cow No. 118, which shows individual variations in this as well as in the other constants. A high iodin number is usually associated with a low Reichert-Meissl number and a low saponification number. The data of cow No. 118 follow this rule. The variations, however, are not sufficient to justify any special emphasis being placed upon either breed or individuality as a factor in causing variations in the saponification number.

Table 15.—*Average saponification number for each cow, and breed average, by 4-week periods.*

Four-week period No.	Jerseys.				Ayrshires.		
	No. 4.	No. 99.	No. 118.	Average for Jerseys.	No. 300.	No. 301.	Average for Ayrshires.
1	231.1	230.6	228.5	230.1	232.6	236.9	234.7
2	233.1	232.1	224.7	229.9	230.7	234.1	232.4
3	232.9	229.5	229.6	230.7	232.3	232.0	232.1
4	229.1	232.3	229.0	230.1	224.8	230.4	227.6
5	230.7	227.7	230.2	229.5	229.2	227.5	228.4
6	229.0	231.7	226.6	229.1	230.1	229.7	229.9
7	227.8	227.3	229.4	228.2	224.5	219.6	222.0
8	229.4	239.8	224.8	231.3	222.0	228.3	225.1
9	234.4	234.3	225.1	231.3	223.9	228.4	226.1
10	235.9	231.4	227.6	231.6	217.2	224.3	220.8
11		229.4	237.0	233.2		216.2	216.2
12		219.6	223.9	221.8		218.7	218.7
13			219.5	219.5		221.3	221.3
14			219.1	219.1			
True total average	231.3	228.6	227.2	228.9	228.4	227.9	228.2

Four-week period No.	Holsteins.				Shorthorns.		
	No. 205.	No. 206.	No. 209.	Average for Holsteins.	No. 400.	No. 402.	No. 403.	Average for Shorthorns.
1	242.2	230.7	237.2	233.4	232.3	234.3	234.3	233.6
2	229.3	228.3	230.6	229.4	231.7	233.9	225.4	230.3
3	229.0	242.4	231.6	234.3	224.2	229.8	228.1	227.4
4	232.9	233.7	230.8	232.8	230.0	223.0	229.9	227.6
5	230.8	232.4	228.3	230.5	229.4	228.3	226.4	228.0
6	228.7	231.2	229.0	229.6	227.2	224.3	230.1	227.2
7	228.1	229.7	224.0	227.3	223.9	223.7	224.6	224.1
8	227.0	225.6	222.4	225.0	226.5	222.7	225.1	224.8
9	225.0	224.4	222.0	223.8	224.9	215.8	223.8	221.5
10	223.9	219.9	219.2	221.0	220.5	211.5	226.4	219.5
11	226.3	216.4	222.0	221.6	216.8		226.6	221.7
12	220.8		230.3	225.5				
13	210.1		215.3	212.7				
14	205.9			205.9				
True total average	228.2	230.1	229.1	229.1	227.6	226.9	227.9	227.6

THE MELTING POINT OF THE FAT.

The melting point was determined according to Wiley's method. An examination of the data given in Table 16 shows a close agreement in the melting point for all of the animals. Apparently there is no variation in the melting point that could reasonably be attributed either to the breed or to the individuality of the animal supplying the samples. A marked variation is noticeable due to the advance in lactation period, but this is regardless of the individual or breed.

Table 17 gives a summary for comparison of the constants of the fat for the four breeds.

TABLE 16.—*Average melting point of the fat for each cow, and breed average, by 4-week periods.*

Four-week period No.	Jerseys.				Ayrshires.		
	No. 4.	No. 99.	No. 118.	Average for Jerseys.	No. 300.	No. 301.	Average for Ayrshires.
	°C.	°C.	°C.	°C.	°C.	°C.	°C.
1	32.36	24.94	26.62	27.97	34.80	32.07	34.44
2	32.63	33.24	32.66	32.84	33.39	33.21	33.30
3	33.39	33.36	33.31	33.35	33.45	32.61	33.03
4	32.25	34.53	33.31	33.36	33.54	32.80	33.17
5	33.30	33.78	33.80	33.63	33.74	33.85	33.79
6	33.44	34.08	33.40	33.64	33.87	32.98	33.43
7	32.94	34.07	33.92	33.64	33.83	33.98	33.90
8	33.24	34.33	33.66	33.74	33.30	33.55	33.43
9	33.03	34.64	33.39	33.69	33.30	33.33	33.32
10	32.97	33.81	33.59	33.46	34.04	33.10	33.57
11	....	34.88	33.81	34.35	....	34.35	34.35
12	....	34.35	33.68	34.02	....	33.23	33.23
13	....	....	33.46	33.46	....	33.28	33.28
14	....	....	33.50	33.50	....	....	....
True total average	32.91	32.95	32.99	32.95	33.75	33.20	33.47

Four-week period No.	Holsteins.				Shorthorns.			
	No. 205.	No. 206.	No. 209.	Average for Holsteins.	No. 400.	No. 402.	No. 403.	Average for Shorthorns.
	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.
1	33.41	32.95	32.58	32.98	33.91	32.69	32.70	33.10
2	32.67	33.52	32.16	32.78	32.99	32.79	33.32	33.08
3	33.39	31.94	32.06	32.46	31.61	33.20	32.70	32.50
4	33.76	32.06	31.84	32.55	33.15	33.09	32.60	32.95
5	33.02	32.47	33.04	32.84	33.01	32.95	33.15	33.04
6	32.93	32.47	31.69	32.36	33.88	33.99	32.98	32.62
7	32.88	32.64	32.30	32.61	33.63	33.76	32.54	33.31
8	32.98	33.13	32.78	32.96	34.13	33.79	32.65	33.52
9	33.26	32.81	32.85	32.97	34.21	34.65	33.14	34.00
10	33.09	32.92	33.82	33.28	35.40	36.31	33.28	34.99
11	33.01	38.80	33.15	34.99	36.49	....	32.83	34.66
12	32.54	....	35.45	33.99	....	....	....	....
13	41.80	....	37.39	39.59	....	....	....	....
14	48.34	....	....	48.38	....	....	....	....
True total average	33.76	32.87	32.02	32.88	33.56	33.37	32.89	33.23

TABLE 17.—*Average chemical and physical constants of the fat by breeds.*

Breed.	Relative size of fat globules.	Iodin number.	Saponification number.	Reichert-Meissl number.	Melting point.
					°C.
Jersey	328	30.52	228.9	26.73	32.95
Ayrshire	150	31.61	228.2	25.93	32.47
Holstein	142	34.20	229.1	25.46	32.88
Shorthorn	282	34.36	227.6	26.23	33.23

SUMMARY AND CONCLUSIONS.

1. The data presented show the influence of the breed and the individual upon the composition of the milk and upon the constants of the fat as evidenced by 11 cows, including 3 each of the Jersey, Holstein, and Shorthorn breeds, and 2 of the Ayrshire breed. These cows were kept upon a uniform ration and the samples represent an entire lactation period for each. A compilation is also given which includes all complete analyses of the milk of purebred animals for entire lactation periods published up to the present by American experiment stations.

2. The average percentage of total solids is highest with the Jersey and lowest with the Holstein. The fat represents 34.9 per cent of the total solids with the Jersey breed and 28 per cent for the Holsteins. The relation of the fat to the total solids is influenced by breed especially and to some extent by the individual in the breed.

3. The data corroborate the well-known facts regarding the variations in fat content due to breed.

4. The breed exerts a decided influence upon the protein content. A low average percentage of fat goes with a low protein content, although the ration is not constant. Breeds such as the Jersey, having a high fat content in the milk, also have a high protein content; they also have a higher ratio of fat to protein.

5. The proportion of the total protein present as casein does not seem to bear any special relation to the breed, although some individual variations are observed.

6. The ratio of casein to the fat varies uniformly with the breed. The variation between the Ayrshire, Shorthorn, and Holstein is slight, but the Jersey has more fat in proportion to the casein.

7. The sugar content of milk does not show much variation either with the breed or with the individual. Our data showed a somewhat lower figure for the Holsteins than for the Ayrshires, Shorthorns, or Jerseys.

8. The data presented show the well-known breed characteristics regarding the size of the fat globules, those in the Jersey being the largest, followed in order by the Shorthorn, Ayrshire, and Holstein.

9. The breed apparently is a factor having some influence on the Reichert-Meissl number. The highest was found with the Jersey, while the Holsteins had somewhat lower figures.

10. The influence of the breed is shown on the iodin number. The Holsteins and Shorthorns have a noticeably higher number than the Jersey, with the Ayrshire coming between.

11. Little influence due to breed or individuality can be observed with the saponification number.

12. The melting point of the fat shows no variation that may be attributed to breed and but little with the individual animals.

13. With the exception of the size of the fat globules, the fat constants are far less influenced by the breed and the individuality of the animals than by the stage of the lactation period. The feed of the animal is probably a greater factor than breed or individuality in influencing the nature of the fat.

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BUREAU OF ANIMAL INDUSTRY.—BULLETIN 157.
A. D. MELVIN, CHIEF OF BUREAU.

VARIATIONS IN THE COMPOSITION AND PROPERTIES OF MILK FROM THE INDIVIDUAL COW.

BY

C. H. ECKLES,
Professor of Dairy Husbandry, University of Missouri,

AND

ROSCOE H. SHAW,
Chemist, Dairy Division, Bureau of Animal Industry.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Animal Industry,
Washington, D. C., July 12, 1912.

Sir: I have the honor to transmit, and to recommend for publication as a bulletin in the bureau series, the accompanying manuscript entitled "Variations in the Composition and Properties of Milk from the Individual Cow," by Messrs. C. H. Eckles, professor of dairy husbandry, University of Missouri, and Roscoe H. Shaw, of the Dairy Division of this bureau.

This paper is the third in the series of reports on milk-secretion investigations which are being conducted at the Missouri Agricultural Experiment Station in cooperation between the Dairy Division and the Missouri station. The previous reports, which have been prepared for publication as Bulletins 155 and 156 of this bureau, have dealt respectively with the influence of the stage of lactation and the influence of the breed and individuality of the cows upon the composition of the milk.

Respectfully,

A. D. Melvin,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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VARIATIONS IN THE COMPOSITION AND PROPERTIES OF MILK FROM THE INDIVIDUAL COW.

INTRODUCTION.

This is the third in a series of reports giving the results of investigations in regard to the influence of certain factors upon the composition and properties of normal milk. Previous publications have given data in regard to variations due to the stage of lactation and variations due to the breed and individuality of the animal.[1] The present paper gives data concerning three factors in the milk from the individual cow, namely, (1) the normal variations from milking to milking, (2) the composition of morning compared with evening milk, and (3) the composition of the first as compared with the last milk drawn.

It is a well-known fact that the composition of milk, at least so far as the percentage of fat is concerned, varies constantly and often quite widely from day to day, and even from milking to milking. No further investigation would be necessary to establish this fact, although it is impossible to set any definite limits as to what may be expected in this respect. Among the causes that are usually assigned for these variations is the influence of weather conditions, changes in the health of the animal, change in milkers, unusual excitement of any kind, and to some extent changes in feed. In many cases it is not possible, with our present knowledge of the physiology of milk secretion, to connect the variations noted with the cause. While the facts regarding the variations in the fat content are well known, the information is very meager regarding the other constituents of the milk, and especially regarding the composition of the fat itself.

Some of the data already published show the variations throughout an entire lactation period. It may be pointed out, however, that a statement of this kind regarding the protein content, for example, really shows the influence due to the stage of lactation rather than to the daily variations. In order to obtain a fair idea as to the amount of daily variations to be expected, the periods covered should not be long enough to introduce variations due to the stage of lactation. Other conditions, as the feed and management of the animal, should remain constant. The variations which will then be found can reasonably be attributed to other causes, such as the physiological condition of the animal.

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[1] Bulletins 155 and 156, Bureau of Animal Industry.

A more extensive knowledge regarding the daily variations in the composition of the milk is of importance to those engaged in the manufacture of dairy products on account of the relation it bears to the manufactured article. A knowledge of the extent and nature of these variations from milking to milking is perhaps of the greatest importance in connection with the use of milk as food, especially for infant feeding. For such purposes it is highly desirable to know if the constituents of the milk, such as the protein and sugar, vary from milking to milking, as the fat is known to do, or whether these constituents remain reasonably constant. So far little is known regarding the relation of the nature of the fat to its use as food, but whatever importance may be attributed to this factor, it is well to know what variations to look for from one day to another. The chemist who is concerned with the inspection of milk for the purpose of detecting adulteration is also greatly in need of this information, and he is constantly required to employ all available knowledge on this subject.

Another reason for beginning this particular series of investigations was the question of daily variations in connection with the sampling of milk from individual cows where the period of investigation covers a considerable length of time. The question here concerned is, How long a period must be included in the sample to obtain a fair representation of the composition of the milk the animal is producing? For example, in carrying on investigations in regard to the influence of feed upon the properties of milk it might be possible to obtain an entirely erroneous idea as to the composition of the milk and the nature of the fat if daily variations in the composition of the fat are large and the sampling period is short.

THE ANIMALS USED, FEED AND MANAGEMENT.

The animals used were all purebred registered animals of the breeds indicated. The following statement gives the details regarding the individuals supplying the samples analyzed:

Cow No.	Breed.	Age (years).	Days in milk.
303 (milked twice daily)	Ayrshire	3	180
205 (milked twice daily)	Holstein	6	89
209 (milked twice daily)	do	5	289
320 (milked twice daily)	Jersey	11	98
400 (milked twice daily)	Shorthorn	5	102
209 (milked three times daily)	Holstein	6	44
207 (milked four times daily)	do	9	14

In carrying out these experiments the animals were fed a uniform ration both in kind and amount during the period covered by the samples. In this way variations due to the ration fed were eliminated. The cows were milked by the same milker, and the intervals between milkings were uniformly 12 hours, except in the cases of cow 209, milked three times daily at eight-hour intervals, and cow 207, milked four times daily at six-hour intervals. Cows 205, 320, and 400 were fed a ration consisting of alfalfa hay, 2 parts, and a mixture of corn, bran, and oats, 1 part. Cows 303 and 209 were turned in a bluegrass pasture during the day, and in addition received a uniform grain ration consisting of a mixture of corn 4 parts, bran 2 parts, and linseed-oil meal 1 part.

Cow 209 when milked three times daily and cow 207 when milked four times daily received a still different ration, but the proportion between the constituents was kept the same and the total quantity fed daily was the same in order that the variations found could not be attributed to the feed.

METHODS OF SAMPLING AND PREPARATION OF SAMPLES FOR ANALYSIS.

The milk was weighed immediately after milking and the entire amount brought to the laboratory. From this a subsample was prepared for analysis. The cream was separated from the remainder of the milk with a small cream separator and the cream secured was churned in a glass jar. This butter was melted to supply the fat sample for analysis. The measurements of color of the butterfat were made with the Lovibond tintometer. The methods followed in the chemical analyses are those recognized by the Association of Agricultural Chemists.[1] Further details in regard to the methods followed will be found in the first report of these investigations in Bulletin 155, Bureau of Animal Industry.

THE VARIATIONS FROM MILKING TO MILKING.

The detailed analyses of the milk from each of the 7 cows in this investigation are found in the three tables forming the Appendix at at the end of this bulletin. Table I shows the variations from milking to milking of the 5 cows which were milked twice daily. Table II gives the data for cow 209 milked three times daily, and Table III for cow 207 milked four times daily.

PROTEIN.

Table 1 below is a summary showing the variations in total protein for the 7 animals. The most striking fact in regard to the protein is the comparatively small variation. More than 90 per cent of the analyses made showed a variation of less than 0.2 per cent from the average for the animal supplying the sample, and no samples show a variation of more than 0.3 per cent from the average. As compared with the other constituents of milk and with the composition of the fat these variations are small. The conclusion to be drawn from this is that the variation in the total protein from milking to milking is comparatively small, and only in exceptional cases would it be sufficient to be of importance in connection with the use of milk as human food. From the standpoint of taking samples for chemical analyses these variations would have to be taken into account, but a fair sample regarding the amount of protein in the milk of a certain cow may be secured by taking the average of a comparatively few samples.

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[1] See Bulletin 107 (revised), Bureau of Chemistry, U. S. Department of Agriculture, 1908.

TABLE 1.—*Average variations in total protein from milking to milking.*

Cow No.	Breed.	Number of milkings.	Total protein.			Variations from average.	
			Average.	Highest.	Lowest.	Less than 0.2 per cent.	Between 0.2 and 0.3 per cent.
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
303 (milked twice daily)......	Ayrshire....	28	3.21	3.38	2.93	93.0	7.0
205 (milked twice daily)......	Holstein....	28	3.02	3.19	2.74	96.4	3.6
209 (milked twice daily)......	.....do......	28	3.31	3.45	3.13	100.0	....
320 (milked twice daily)......	Jersey......	28	3.58	3.83	3.32	89.3	10.7
400 (milked twice daily)......	Shorthorn...	28	3.59	3.83	3.45	93.0	7.0
209 (milked three times daily).	Holstein....	21	2.75	3.19	2.55	95.0	5.0
207 (milked four times daily)..	.....do......	20	2.57	2.74	2.30	90.0	10.0

SUGAR.

Table 2 is a summary showing the extent of variations in the sugar content. The sugar is usually considered to be the least variable of any constituent of milk, but our results indicate that it may be expected to vary rather more than the total protein. Some animals seem to show a wider variation in the amount of sugar than others. A variation of 0.5 per cent from the average is not uncommon with certain individuals, but about 90 per cent of the analyses show a variation of less than 0.2 per cent.

TABLE 2.—*Average variations in sugar from milking to milking.*

Cow No.	Breed.	Number of milkings.	Sugar content.			Variations from average.			
			Average.	Highest.	Lowest.	Less than 0.2 per cent.	0.2 to 0.4 per cent.	0.4 to 0.6 per cent.	0.6 to 0.8 per cent.
			Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
303 (milked twice daily).	Ayrshire..	28	5.32	5.65	4.98	89.3	10.7	....	....
205 (milked twice daily).	Holstein..	28	5.10	5.49	4.64	35.7	57.1	7.2	....
209 (milked twice daily).	...do......	28	4.55	5.05	4.29	89.0	7.1	3.6	....
320 (milked twice daily).	Jersey.....	28	4.91	5.46	4.54	46.4	39.2	10.5	3.5
400 (milked twice daily).	Shorthorn	28	5.37	5.70	4.83	81.4	14.8	....	3.7
209 (milked three times daily).	Holstein..	21	4.68	5.23	4.46	85.0	10.0	5.0	....
207 (milked four times daily).	...do......	20	4.55	4.71	4.25	90.0	10.0	....	....

FAT.

As already stated, it is a well-known fact that the fat varies from milking to milking. Table 3 gives the variations with this constituent for the 7 cows used in this investigation. The extreme variation reaches almost 2 per cent. Only 56 per cent of the samples come within 0.3 per cent of the average; 27.7 per cent range between 0.3 and 0.6 per cent; 11.7 per cent vary between 0.6 and 0.9 per cent from the average, and 4.6 per cent vary more than 0.9 per cent from the average.

A sample taken from a single milking is of little value as an indication of the quality of milk produced by any cow. When the number of milkings per day is increased to three or four the variations in the fat content become greater.

TABLE 3.—*Average variations in fat content from milking to milking.*

Cow No.	Breed.	Number of milkings.	Fat content.			Variations from average.			
			Average.	Highest.	Lowest.	Less than 0.3 per cent.	Between 0.3 and 0.6 per cent.	Between 0.6 and 0.9 per cent.	Over 0.9 per cent.
			Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
303 (milked twice daily).	Ayrshire...	27	3.93	4.36	3.49	77.7	22.3	....	....
205 (milked twice daily).	Holstein...	28	3.07	3.79	2.40	39.3	46.4	14.3	....
209 (milked twice daily).	.....do.....	28	3.18	3.67	2.71	85.7	14.3	....	....
320 (milked twice daily).	Jersey......	28	5.31	6.31	4.56	50.0	25.0	17.9	7.1
400 (milked twice daily).	Shorthorn..	27	4.08	5.29	3.46	63.0	29.6	3.7	3.7
209 (milked three times daily).	Holstein...	20	2.98	3.63	2.24	45.0	30.0	25.0	....
207 (milked four times daily).	.....do.....	19	2.62	4.15	1.67	31.6	26.2	21.1	21.1

THE REICHERT-MEISSL NUMBER.[1]

Table 4 gives the data regarding this constant of the fat and shows what may be expected in the way of variations. The limit of error in making this determination is generally considered to be 0.5. Fifty-eight per cent of the determinations vary less than 1 from the average; 23.4 per cent vary between 1 and 2; 13.4 per cent between 2 and 3; 4.6 per cent between 3 and 4; and 0.5 per cent more than 4.

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[1] This and the succeeding constants of the fat were determined by official methods, the details of which may be found in Bulletin 107 (revised), Bureau of Chemistry, United States Department of Agriculture. For the benefit of those who may be unfamiliar with the terms the following explanation may be helpful. The Reichert-Meissl number is an arbitrary measure of the volatile acids of which butyric is the principal one in butterfat. The figures do not show the percentages of the acid, but serve as a means of comparing different fats with reference to their volatile constituents. The iodin absorption number indicates relatively the amount of iodin a fat will absorb. Since the only fatty acid found to exist in butterfat which has the property of absorbing iodin is oleic acid, the iodin absorption number shows relatively the amount of this fatty acid present, but in common with the Reichert-Meissl number the figures do not represent percentages. The saponification number is the number of milligrams of potassium hydroxid required to saponify 1 gram of fat. Since the amount of potassium hydroxid required depends upon the molecular weight of the fat, the saponification number serves as an indicator of the relative percentages of the fatty acids of high and low molecular weights present.

On the whole, the fluctuation in the Reichert-Meissl number is quite marked. It is impossible to say with our present knowledge what are the causes of this wide fluctuation. It is evident that to obtain a fair sample for this determination more than one milking should be represented. The authors have been unable to find any data regarding the significance of the amount of volatile acids from the standpoint of human food.

TABLE 4.—*Average variations in the Reichert-Meissl number from milking to milking.*

Cow No.	Breed.	Number of milkings.	Reichert-Meissl number.			Variations from average.				
			Average.	Highest.	Lowest.	Less than 1.	Between 1 and 2.	Between 2 and 3.	Between 3 and 4.	Above 4.
						P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
303 (milked twice daily)	Ayrshire...	27	21.99	24.14	18.46	44.4	33.3	18.5	3.7	....
205 (milked twice daily).	Holstein...	28	27.35	30.81	25.90	68.0	25.0	3.5	3.5	....
209 (milked twice daily).	.....do.....	27	19.24	23.65	18.39	70.4	18.6	7.4	....	3.6
320 (milked twice daily).	Jersey	27	25.89	28.01	23.77	51.9	37.0	11.1	....	....
400 (milked twice daily).	Shorthorn..	27	26.15	28.81	23.45	70.4	11.1	18.5	....	....
209 (milked three times daily).	Holstein...	21	29.16	30.43	27.69	81.0	19.0	....	....	....
207 (milked four times daily).	.....do.....	20	30.67	34.28	27.15	20.0	20.0	35.0	25.0	....

THE IODIN NUMBER.

Table 5 shows the variations in the iodin number. The limit of error in making this determination is generally considered to be 0.5. The table shows that only 48 per cent of the total came within 1 of the average for the cow supplying the sample; 27.4 per cent varied between 1 and 2; while 15.8 per cent ranged between 2 and 3 from the average; and 8.8 per cent varied more than 3. These data indicate that rather wide variations are to be expected in the iodin number from day to day.

TABLE 5.—*Average variations in the iodin number from milking to milking.*

Cow No.	Breed.	Number of milkings.	Iodin number.			Variations from average.			
			Average.	Highest.	Lowest.	Less than 1.	Between 1 and 2.	Between 2 and 3.	Above 3.
						Per ct.	*Per ct.*	*Per ct.*	*Per ct.*
303 (milked twice daily).	Ayrshire..	28	41.32	44.62	40.04	25.9	25.9	29.6	18.5
205 (milked twice daily).	Holstein..	28	32.70	34.46	30.17	71.4	25.0	3.6	....
209 (milked twice daily).	.....do....	28	41.98	45.37	34.28	18.5	33.3	22.2	26.0
320 (milked twice daily).	Jersey.....	28	24.18	28.27	21.98	59.3	22.2	11.1	7.4
400 (milked twice daily).	Shorthorn	28	30.63	31.91	28.77	63.0	37.0	....	....
209 (milked three times daily).	Holstein..	21	32.73	34.49	30.73	47.6	33.3	19.1	....
207 (milked four times daily).	.....do....	20	41.17	44.34	38.28	50.0	15.0	25.0	10.0

THE SAPONIFICATION NUMBER.

Table 6 is a summary of the variations in the saponification number as found with the 7 cows. The limit of error in making this determination is considered as being 2. The table shows that on the average 62.2 per cent of the determinations varied less than 2 from the average, or no more than the limit of error; 24.7 per cent ranged between 2 and 4 of the average; 9.3 per cent between 4 and 6; while 3.7 per cent varied more than 6. As with the other constants of the fat, we find here considerable variation from milking to milking. A study of the tables fails to indicate any relation between the iodin number and the amount of fat or of any other constituent. An increase in the iodin number in most cases is accompanied by a decline in the Reichert-Meissl number and in the saponification value. This relation is commonly found in butterfat.

TABLE 6.—*Average variations in the saponification number from milking to milking.*

Cow No.	Breed.	Number of milkings.	Saponification number.			Variations from average.			
			Average.	Highest.	Lowest.	Less than 2.	Between 2 and 4.	Between 4 and 6.	Above 6.
						Per ct.	*Per ct.*	*Per ct.*	*Per ct.*
303 (milked twice daily).	Ayrshire..	28	236.2	247.3	231.2	48.2	33.3	11.1	7.4
205 (milked twice daily).	Holstein..	28	227.9	234.0	224.6	67.8	21.4	7.2	3.6
209 (milked twice daily).	.....do....	28	234.2	242.4	226.1	42.3	19.2	30.8	7.7
320 (milked twice daily).	Jersey.....	28	235.3	240.8	232.1	66.7	22.2	11.1	....
400 (milked twice daily).	Shorthorn.	28	232.7	239.7	224.2	70.4	22.2	....	7.4
209 (milked three times daily).	Holstein..	21	230.1	232.1	226.6	90.5	9.5	....	....
207 (milked four times daily).	.....do.....	20	226.3	231.0	223.1	50.0	45.0	5.0	....

THE MELTING POINT.

A summary of the data showing this constant of the fat is given in Table 7. The range in variation here is small. It may be seen that 96.5 per cent of all vary less than 1° from the average. This result corresponds with our data already published in indicating that the melting point of the fat is not influenced to any great extent by a small change in the other constants of the fat. The melting point of a mixture of fats can not be predicted from the melting points of the fats themselves, according to Lewkowitsch.[1]

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[1] Lewkowitsch, J. Chemical technology and analysis of oils, fats, and waxes. London, 1909. See vol. 1, p. 94.

TABLE 7.—*Average variations in the melting point from milking to milking.*

Cow No.	Breed.	Number of milkings.	Melting point.			Variations from average.	
			Average.	Highest.	Lowest.	Less than 1 degree.	Between 1 and 2 degrees.
			° *C.*	° *C.*	° *C.*	*Per cent.*	*Per cent.*
303 (milked twice daily)	Ayrshire	28	33.34	34.45	32.30	88.9	11.1
205 (milked twice daily)	Holstein	28	34.09	35.05	33.30	100.0	....
209 (milked twice daily)	do	28	33.46	34.40	32.95	96.3	3.7
320 (milked twice daily)	Jersey	28	35.43	36.10	34.55	100.0	....
400 (milked twice daily)	Shorthorn	28	33.92	34.40	33.45	100.0	....
209 (milked three times daily)	Holstein	21	32.54	34.27	31.57	90.5	9.5
207 (milked four times daily)	do	20	34.01	34.97	33.40	100.0	....

COMPARISON OF MORNING AND EVENING MILK.

The data which have been given make it possible to compare the composition of morning milk with that milked in the evening. A large amount of data is already available regarding the variation in the fat content of milk as brought about by this factor. Practically none, however, has been published regarding the variations in the constituents other than the fat or regarding changes in the nature of the fat itself.

Fleischmann[1] found morning milk slightly richer than evening, but decided that the fat content varied with the interval between milkings. Sufficient data have been published by various authors to show the accuracy of the above statement. As a rule, when a cow is milked twice daily at intervals of equal length there is only a small variation in the average fat content of the milk. The variations found under these conditions seem to depend upon the individuality of the animals.

Table 8 is compiled from those that have preceded and gives the average figures for the morning and evening milking for each animal. Taking first the animals where the interval between milking was uniformly 12 hours, it will be noted that with 4 out of the 5 cows the yield of milk was slightly greater in the morning.

No variation in the protein content can be observed that may be attributed to the factor under consideration. The same may be said of the sugar. The fat is noticeably higher in the morning with 3 of the cows and apparently unchanged with 2.

The Reichert-Meissl number with each of the 5 animals is lower in the evening.

The iodin number in each case is higher in the evening sample.

The saponification value for the evening sample is decidedly lower with 2, slightly lower with 2, and higher for 1.

The melting point shows no variation sufficient to be taken into account. The same is true in regard to the size of the fat globules.

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[1] Fleischmann, Wilhelm. Untersuchung der Milch von sechzehn Kühen. Landwirtschaftliche Jahrbücher, vol. 20, sup. 2. Berlin, 1891.

The physical constants of the fat show slight variations, but hardly sufficient to be taken into account.

The samples from the 2 animals that were milked three and four times daily showed wider variations than those from the cows milked twice only, although no appreciable variation was found with the total protein, sugar, and ash.

The per cent of fat varied considerably with the different milkings. The highest fat content was found in milk drawn near the middle of the day.

In general the composition of the milk plasma does not seem to vary appreciably from morning to evening when the interval between milkings is the same. This statement also holds good when the number of milkings is increased from two to three or four per day. The per cent of fat shows some variation, mostly depending upon the individual, and this variation is wider when the cow is milked more than twice daily. The fat content of morning milk is usually slightly higher. There seems to be a fairly constant variation in the chemical and physical constants of the fat between morning and evening. This is most noticeable with the volatile acids, which tend to be higher in morning milk, and with the iodin number, which is generally higher in the evening sample.

TABLE 8.—*Comparison of morning and evening milk—Average determinations for each milking.*

COWS MILKED TWICE DAILY.

Cow No.	Hour milked.	Average yield of milk.	Total protein.	Ash.	Sugar.	Fat.	Reichert-Meissl number.	Iodin number.	Saponification number.	Melting point of fat.	Relative size of fat globules.
		Pounds.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*				°*C.*	
303...	5.30 a. m.....	11.2	3.16	....	5.37	3.96	22.92	39.94	238.1	33.37	132
	5.30 p. m.....	12.2	3.24	....	5.26	3.92	21.12	43.33	234.4	33.31	139
205...	5.30 a. m.....	9.2	3.09	....	5.24	3.45	27.52	32.53	227.7	34.13	161
	5.30 p. m.....	8.0	2.95	....	4.96	2.70	27.17	32.87	228.2	34.05	133
209...	5.30 a. m.....	14.4	3.28	....	4.57	3.17	20.52	41.60	235.5	33.35	68
	5.30 p. m.....	13.6	3.33	....	4.54	3.18	19.43	42.34	231.9	33.56	68
320...	5.30 a. m.....	10.1	3.63	....	4.92	5.64	26.24	23.59	235.8	35.45	373
	5.30 p. m.....	9.2	3.54	....	4.84	4.98	25.55	24.53	234.9	35.40	322
400...	5.30 a. m.....	10.1	3.57	....	5.41	4.26	26.54	29.59	232.8	33.98	420
	5.30 p. m.....	9.3	3.61	....	5.32	3.88	25.88	30.97	232.7	33.85	384

COW MILKED THREE TIMES DAILY.

209:..	5 a. m.......	23.7	2.73	0.73	4.77	2.47	29.49	31.75	231.1	32.40	70
	1 p. m.......	19.1	2.70	.71	4.53	3.26	29.39	33.01	230.2	32.38	67
	9 p. m.......	14.9	2.82	.72	4.73	3.25	28.60	33.43	229.1	32.83	73

COW MILKED FOUR TIMES DAILY.

207...	4 a. m.......	28.1	2.62	0.72	4.61	2.07	30.41	40.63	226.4	34.27	160
	10 a. m......	23.0	2.57	.72	4.48	3.46	30.75	41.19	226.0	33.99	166
	4 p. m.......	23.2	2.63	.73	4.61	2.51	30.82	41.06	226.4	33.77	153
	10 p. m......	22.3	2.46	.70	4.50	2.60	30.68	41.79	226.8	33.98	224

THE COMPOSITION OF THE FIRST AND LAST MILK DRAWN.

It has long been well known that the last milk drawn from a cow, commonly known as the strippings, contains a much larger per cent of fat than does the first milk drawn from the same cow, often spoken of as the foremilk. Kirchner[1] gives figures typical of this variation. According to his data the fat content increases gradually as the milking progresses, while the solids other than fat remain practically constant in all parts of the milking.

The investigation herein reported was made for the purpose of supplying additional data on this factor, especially in regard to the variation in the composition and nature of the fat in the foremilk and the strippings. This information is given in Tables 9 and 10. In taking the samples of foremilk represented in Table 9, 100 c. c. of milk was taken from each teat of the cow, the 4 portions being mixed to form the sample for analysis. The sample of strippings was secured when the milk was nearly out of the udder. A sample of 100 c. c. was then taken from each teat. If more could be drawn after taking this amount it was drawn into a second flask and sufficient added from the first to make up 100 c. c. One sample was then made by mixing the 100 c. c. sample from each teat.

It is probable that a still more marked variation would have been found between the first and last milk drawn had the samples taken been smaller and thus represented the extremes of the milking. The samples supplying the fat for the analyses given in Table 10 were taken in the manner already described, except that the samples from each cow were put together in the form of a composite sample representing 7 days. This was done in order to secure sufficient fat from which to make the determinations.

The following is the average analysis of the first and last milk, taken from Table 9:

	Total protein.	Sugar.	Fat.	Ash.	Total solids.	Relative size of fat globules.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	
First milk	3.58	5.30	1.87	0.75	10.67	139
Strippings	3.38	5.33	6.28	.70	14.86	215

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[1] Kirchner, W. Handbuch der Milchwirtschaft. Berlin, 1898. See p. 56.

The only difference that is at all striking is that of the fat. Since the variation in this constituent is so marked, the following figures are given, which represent the composition of the milk plasma or the milk minus the fat:

	Total protein.	Sugar.	Ash.
	Per cent.	*Per cent.*	*Per cent.*
First milk	3.65	5.40	0.77
Strippings	3.60	5.68	0.75

It is evident from these figures that the change in composition of the first milk drawn to the last is confined to the amount of fat present. The milk plasma remains practically the same in composition.

The data given in Table 9 show that the larger the quantity of milk produced the greater is the variation in fat content and in the relative size of the fat globules between the first and last milk drawn. From the further data in Table 10 it may be observed that the quantity of milk produced is an important factor in determining the extent of the variation from the foremilk to the strippings. With the cows producing the small quantity of milk the strippings range from twice to three times the fat content of the foremilk, while with those producing large quantities the strippings contain 3 to 10 times as much as the foremilk.

The higher fat content of the last milk drawn has been explained in several ways. The most plausible seems to be that given by Kirchner.[1] According to this author the fat globules are held back mechanically in the fine passageways of the udder and escape in larger quantities in the last milk drawn. The data given support this theory by the additional fact, not given by the authority quoted, that the larger the production of milk the greater is the increase in fat as the milking progresses. This may be explained by the supposition that in the heavier milking cows the udder is more congested and the opening of the ducts made smaller by compression.

The larger fat globules would also be held back in the small ducts more than the smaller ones. This would account for the larger fat globules in the strippings and for the greater variation in size from foremilk to strippings when the production of milk is large.

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[1] Kirchner, W. Handbuch der Milchwirtschaft. Berlin, 1898 See p. 58.

TABLE 9.—*Analysis of first milk and strippings.*

Breed.	Milk yield per day.	Date of milking.	Specific gravity of milk.	Water.	Total solids.	Ash.	Total nitrogen.	Total protein (N. x 6.38).	Casein nitrogen.	Albumin nitrogen.	Sugar.	Fat.	Relative size of fat globules.
	Pounds.			*Per cent.*	*Per cent.*	*Per ct.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	
Jersey........	36.8	Aug. 23 Foremilk....................	1.0349	89.54	10.46	0.71	0.54	3.45	0.42	0.048	5.79	1.59	139
		Strippings....................	1.0314	85.44	14.56	.69	.51	3.25	.41	.055	5.64	5.92	213
	41.1	Aug. 25 Foremilk....................	1.0358	89.94	10.06	.75	.52	3.32	.36	.070	5.23	1.37	122
		Strippings....................	1.0274	84.85	15.16	.70	.49	3.13	.26	.060	4.75	6.92	313
Holstein......	34.5	Aug. 19 Foremilk....................	1.0323	90.57	9.43	.73	.47	3.00	.36	.052	5.31	1.42	87
		Strippings....................	1.0265	86.43	13.57	.69	.44	2.81	.33	.056	6.06	5.82	139
	38.9	Aug. 25 Foremilk....................	1.0333	90.76	9.24	.77	.47	3.00	.36	.041	5.23	.88	87
		Strippings....................	1.0284	87.14	12.66	.72	.45	2.87	.34	.053	4.85	4.80	149
Shorthorn...	39.6	Aug. 19 Foremilk....................	1.0343	90.16	9.84	.74	.50	3.19	.36	.076	5.71	1.31	91
		Strippings....................	1.0283	85.62	14.38	.63	.48	3.06	.35	.078	6.10	6.23	190
	41.9	Aug. 25 Foremilk....................	1.0350	89.66	10.34	.77	.51	3.25	.39	.059	5.44	1.35	85
		Strippings....................	1.0298	85.68	14.32	.69	.50	3.19	.37	.059	5.74	5.54	235
Jersey........	15.4	Aug. 25 Foremilk....................	1.0300	89.19	10.81	.75	.52	3.32	.37	.057	4.46	2.96	183
		Strippings....................	1.0296	87.28	12.72	.70	.51	3.25	.41	.047	4.39	4.39	226
	14.1	Sept. 8 Foremilk....................	1.0300	89.84	10.16	.76	.53	3.84	.39	.068	4.51	2.45	180
		Strippings....................	1.0272	85.82	14.18	.70	.52	3.32	....	.061	....	6.05	309
Ayrshire......	11.3	Aug. 25 Foremilk....................	1.0340	89.86	10.14	.70	.58	3.70	.45	.069	....	1.09	52
		Strippings....................	1.0244	81.65	18.35	.64	.54	3.45	.42	.048	4.91	10.00	200
	12.9	Oct. 12 Foremilk....................	1.0384	88.50	11.50	.79	.65	4.15	.53	.067	....	1.64	116
		Strippings....................	1.0283	82.83	17.17	.73	.59	3.76	.52	.070	5.35	7.88	207
Jersey.......	6.3	Sept. 8 Foremilk....................	1.0357	86.97	13.03	.75	.66	4.21	.52	.085	....	3.34	186
		Strippings....................	1.0310	83.92	16.08	.71	.64	4.08	.50	.080	5.50	6.92	183
	7.3	Sept. 27 Foremilk....................	1.0357	86.99	13.01	.75	.70	4.47	.55	.074	6.06	3.07	342
		Strippings....................	1.0310	85.06	14.94	.75	.68	4.34	.55	.108	5.35	4.91	215

TABLE 10.—*The composition of the foremilk and strippings as influenced by the quantity of milk produced.*

Breed.	Total milk.	Fat content.			Relative size of fat globules.		
		Fore-milk.	Entire milk.	Strip-pings.	Fore-milk.	Entire milk.	Strip-pings.
	Pounds.	*Per cent.*	*Per cent.*	*Per cent.*			
Jersey	3.0	3.7	6.2	10.3	206	250	264
Do	3.0	3.5	5.3	7.4	88	148	178
Do	3.3	3.2	5.2	7.6	125	120	158
Do	4.0	3.8	5.4	10.0	76	84	109
Shorthorn	7.8	1.4	3.8	8.7	152	232	280
Do	8.1	1.0	3.8	8.8	244	140	224
Do	15.5	0.9	3.1	7.5	51	145	254
Do	16.7	0.4	2.5	7.0	24	94	108
Holstein	12.7	2.0	3.0	5.2	118	146	150
Do	14.0	1.0	2.0	3.0	21	29	48
Do	15.7	1.2	3.0	5.2	56	67	90
Do	20.2	0.2	1.3	4.0	13	59	68
Do	20.2	0.4	1.6	5.3	27	70	122
Do	22.5	1.0	1.6	3.4	60	70	102

Table 11 gives the physical and chemical constants of the fat as found in the first and last milk drawn. The following is an average of this table:

	Reichert-Meissl number.	Iodin number.	Saponification number.	Melting point.	Yellow color.
				°*C.*	
First milk	27.25	34.14	230.1	33.88	39
Strippings	26.32	33.82	228.3	33.91	39

The Reichert-Meissl number on the average is 0.93 lower in the strippings. It is lower with 6 out of the 8 cows supplying the samples.

The iodin number is 0.32 lower on the average in the fat from the strippings and 7 out of the 8 cows show the same variation, the eighth being practically the same. This tendency for a lower iodin number in the strippings while not great enough to be of much importance seems to be the rule.

The saponification number also is lower on the average in the strippings and occurred with 6 out of the 8 animals.

The melting point of the fat and the yellow color seem to be unchanged.

TABLE 11.—*Analysis of fat from first and last milk.*

Cow No.	Average milk per day.	Date of milking.	Reichert-Meissl number.	Iodin number.	Saponification number.	Melting point.	Color.		
							Yellow.	Red.	Light.
	Pounds.					*°C.*			
57	14.4	Sept. 28 to Oct. 5 Foremilk...	28.14	34.09	231.3	34.03	50	2.7	0.3
		Strippings..	28.68	33.47	229.2	33.80	54	3.0	.3
55	15.1	Sept. 28 to Oct. 5 Foremilk...	26.15	36.10	226.8	35.20	52	2.2	.3
		Strippings..	26.25	35.88	224.4	35.07	52	3.0	.3
206	32.9	Sept. 28 to Oct. 5 Foremilk...	26.43	39.64	225.0	33.20	45	1.6	.2
		Strippings..	26.38	38.96	226.3	32.73	45	1.6	.2
210	42.3	Sept. 28 to Oct. 5 Foremilk...	28.40	30.87	229.9	34.67	21	2.0	.2
		Strippings..	25.59	30.63	230.4	34.80	22	2.0	.2
300	27.4	Sept. 28 to Oct. 5 Foremilk...	27.59	28.60	235.4	34.03	50	3.0	.3
		Strippings..	27.27	28.25	231.2	34.20	50	3.0	.3
301	27.5	Sept. 28 to Oct. 5 Foremilk...	28.06	33.32	232.3	33.27	20	1.5	.2
		Strippings..	25.43	33.59	230.7	33.67	16	1.7	.2
403	36.7	Sept. 28 to Oct. 5 Foremilk...	26.53	31.56	233.3	33.17	28	1.7	.2
		Strippings..	25.01	31.37	229.1	33.27	26	1.7	.2
6	12.2	Sept. 28 to Oct. 5 Foremilk...	26.73	38.94	226.9	33.50	50	1.6	.2
		Strippings..	25.97	38.40	225.1	33.73	47	1.6	.2

APPENDIX.

The following tables give the detailed analyses of the milk at each milking from the 7 cows specially used in this investigation. Table I contains the data for the 5 cows milked twice daily, Table II gives the analyses for the cow milked 3 times daily, and Table III for the cow milked 4 times daily.

TABLE I.—*Showing variation from milking to milking—Detailed analyses of milk from cows milked twice daily.*

COW NO. 303.

Date of milking.		Yield of milk.	Specific gravity of milk.	Water.	Total solids.	Total nitrogen.	Total protein (N. x 6.38).	Casein nitrogen.	Albumin nitrogen.	Sugar.	Fat.	Reichert-Meissl number.	Iodin number.	Saponification number.	Melting point of fat.	Relative size of fat globules.
1909.		*Pounds.*		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*				° *C.*	
June 2........	a. m..	11.8	1.0320	87.16	12.84	0.51	3.25	0.41	0.061	5.41	4.09	22.79	39.99	240.1	34.10	204
	p. m..	12.2	1.0314	87.33	12.67	.51	3.25	.41	.068	5.38	3.49	22.11	40.81	234.3	33.80	98
3........	a. m..	12.9	1.0315	87.37	12.63	.50	3.19	.39	.077	5.43	3.71	22.75	37.97	239.5	33.40	120
	p. m..	12.5	1.0320	87.47	12.53	.52	3.32	.39	.060	5.31	3.97	21.22	42.66	233.1	33.65	131
4........	a. m..	11.1	1.0318	87.07	12.93	.50	3.19	.45	.056	5.30	4.08	23.21	33.55	237.4	33.60	125
	p. m..	12.7	1.0315	87.85	12.15	.52	3.32	.40	.057	5.19	3.72	19.79	42.61	233.6	33.55	125
5........	a. m..	12.2	1.0313	87.18	12.82	.51	3.25	.39	.057	5.24	4.01	24.06	87.37	237.4	33.70	121
	p. m..	12.1	1.0324	87.43	12.57	.53	3.38	.41	.063	5.18	3.79	21.91	43.41	234.3	33.30	135
6........	a. m..	12.5	1.0320	87.67	12.33	.50	3.19	.39	.066	5.08	3.94	23.28	40.65	238.1	32.95	59
	p. m..	11.8	1.0328	87.62	12.38	.53	3.38	.41	.047	5.36	4.28	22.11	42.86	233.0	32.75	142
7........	a. m..	12.7	1.0320	88.03	11.97	.50	3.19	.40	.052	5.36	3.62	24.14	39.24	240.4	33.80	117
	p. m..	12.7	1.0318	87.16	12.84	.51	3.25	.38	.052	4.98	4.00	22.11	43.56	233.0	32.30	168
8........	a. m..	10.5	1.0319	87.23	12.77	.50	3.19	.41	.052	5.43	4.06	24.08	40.04	247.3	32.15	129
	p. m..	12.5	1.0319	87.50	12.50	.51	3.25	.39	.057	5.25	3.85	22.00	43.30	233.1	33.15	177
9........	a. m..	12.7	1,0309	87.48	12.52	.51	3.25	.39	.056	5.25	....	21.85	42.26	236.7	33.40	....
	p. m..	12.5	1.0322	87.58	12.42	.52	3.32	.41	.052	5.20	4.04	22.70	41.87	236.4	33.13	159
10........	a. m..	11.6	1.0314	88.02	11.98	.49	3.13	.40	.051	5.83	3.77	23.10	39.98	238.1	33.68	142
	p. m..	12.5	1.0316	87.11	12.89	.50	3.19	.39	.047	5.23	4.24	21.04	44.09	231.2	33.48	205
11........	a. m..	11.6	1.0308	87.20	12.80	.48	3.06	.39	.049	5.26	4.19	23.30	41.76	233.3	33.45	155
	p. m..	12.1	1.0321	87.27	12.73	.51	3.25	.39	.053	5.30	4.20	20.31	44.46	232.8	34.45	123
12........	a. m..	11.7	1.0318	87.50	12.50	.51	3.25	.39	.046	5.65	3.80	20.18	44.15	235.7	32.65	116
	p. m..	12.5	1.0314	87.89	12.11	.50	3.19	.38	.043	5.20	4.03	18.46	44.62	234.8	33.10	110
13........	a. m..	11.7	1.0316	87.51	12.49	.49	3.13	.37	.050	5.63	4.21	....	....	....	....	177
	p. m..	11.5	1.0315	87.95	12.05	.50	3.19	.38	.055	5.35	3.84	21.41	44.02	232.1	32.75	144
14........	a. m..	12.6	1.0304	87.71	12.29	.48	3.06	.36	.045	5.30	4.36	22.50	41.45	235.0	33.45	145
	p. m..	11.8	1.0312	88.03	11.97	.46	2.93	.37	.052	5.33	3.56	19.97	44.12	243.3	33.65	100
15........	a. m..	11.5	1.0313	87.91	12.09	.47	3.00	.37	.043	5.46	3.68	22.77	40.81	236.1	33.45	113
	p. m..	11.7	1.0323	87.65	12.35	.50	3.19	.40	.049	5.44	3.80	20.54	44.21	236.8	33.30	127

TABLE I.—*Showing variation from milking to milking—Detailed analyses of milk from cows milked twice daily*—Continued.

COW NO. 205.

Date of milking.		Yield of milk.	Specific gravity of milk.	Water.	Total solids.	Total nitrogen.	Total protein (N. x 6.38).	Casein nitrogen.	Albumin nitrogen.	Sugar.	Fat.	Reichert-Meissl number.	Iodin number.	Saponification number.	Melting point of fat.	Relative size of fat globules.
1908.		*Pounds.*		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*				° *C.*	
Nov. 16	a. m.	9.5	1.0334	87.22	12.78	0.49	3.13	0.39	0.066	5.30	3.64	25.90	33.58	226.8	34.25	176
	p. m.	7.0	1.0332	89.11	10.89	.46	2.93	.34	.060	4.89	2.61	26.38	32.15	225.7	35.05	131
17	a. m.	10.6	1.0331	87.96	12.04	.49	3.13	.34	.066	4.94	3.33	28.83	33.23	228.4	33.90	......
	p. m.	9.2	1.0329	88.77	11.23	.46	2.93	.36	.042	4.83	2.98	27.97	34.35	234.0	33.30	198
18	a. m.	9.0	1.0333	87.87	12.13	.50	3.19	.38	.058	5.20	3.32	26.43	33.93	233.1	34.15	145
	p. m.	9.6	1.0331	88.96	11.04	.45	2.87	.35	.050	4.86	2.88	26.15	34.46	224.8	33.95	111
19	a. m.	9.1	1.0333	87.55	12.45	.50	3.19	.39	.053	5.41	3.39	28.64	33.25	224.6	33.45	175
	p. m.	8.7	1.0331	89.08	10.92	.48	3.06	.37	.040	5.33	2.57	28.09	32.56	226.7	34.10	129
20	a. m.	9.7	1.0333	88.02	11.98	.50	3.19	.39	.050	5.43	3.04	25.97	32.92	225.5	34.80	141
	p. m.	8.4	1.0332	89.37	10.63	.46	2.93	.35	.059	4.84	2.22	26.04	31.67	226.6	34.50	118
21	a. m.	10.2	1.0331	87.92	12.08	.47	3.00	.37	.057	5.36	3.36	26.64	31.20	227.8	34.85	175
	p. m.	8.9	1.0339	89.09	10.91	.46	2.93	.35	.048	5.05	2.41	26.32	32.45	233.7	33.35	108
22	a. m.	10.1	1.0335	87.58	12.42	.48	3.06	.38	.052	5.23	3.61	26.84	33.07	227.6	34.00	150
	p. m.	9.0	1.0333	88.75	11.25	.47	3.00	.37	.039	5.35	2.77	27.37	32.45	227.7	34.65	133
23	a. m.	10.3	1.0348	87.62	12.38	.48	3.06	.37	.044	5.49	3.54	28.03	31.50	229.2	33.80	158
	p. m.	9.0	1.0330	88.95	11.05	.46	2.93	.36	.040	4.86	2.72	27.23	32.73	226.4	34.00	129
24	a. m.	9.5	1.0354	87.50	12.50	.49	3.13	.37	.048	5.46	3.46	30.81	30.17	230.1	34.40	126
	p. m.	9.1	1.0325	88.78	11.22	.47	3.00	.36	.041	4.89	2.72	29.66	31.15	231.1	34.70	105
25	a. m.	10.5	1.0325	87.74	12.26	.49	3.13	.38	.042	5.38	3.32	27.45	32.65	226.0	34.35	130
	p. m.	8.9	1.0304	89.35	10.65	.43	2.74	.32	.044	4.76	2.56	28.41	33.47	226.4	34.30	95
26	a. m.	9.5	1.0315	88.03	11.97	.46	2.93	.37	.059	4.68	3.24	26.89	32.15	226.2	34.30	127
	p. m.	8.6	1.0318	88.86	11.14	.46	2.93	.36	.046	4.64	2.68	26.49	33.13	227.0	33.95	156
27	a. m.	10.1	1.0314	87.43	12.57	.47	3.00	.37	.039	4.89	3.67	27.79	32.42	227.9	34.10	164
	p. m.	8.0	1.0327	89.20	10.80	.46	2.93	.37	.043	4.94	2.40	27.83	33.60	228.8	33.35	139
28	a. m.	10.4	1.0327	87.63	12.37	.47	3.00	.37	.034	5.25	3.57	27.62	32.96	228.2	33.30	202
	p. m.	8.0	1.0324	88.33	11.67	.49	3.13	.37	.053	5.08	3.11	27.78	32.91	228.8	33.45	143
29	a. m.	9.4	1.0324	87.35	12.65	.48	3.06	.36	.048	5.29	3.79	27.48	32.38	226.6	34.20	213
	p. m.	9.4	1.0304	88.70	11.30	.46	2.93	.34	.050	5.05	3.12	26.70	33.17	226.8	34.05	168

COW NO. 209.

1909.																
June 2	a. m.	14.4	1.0305	88.71	11.29	0.53	3.38	0.38	0.077	4.65	3.07	20.19	38.00	234.8	33.45	73
	p. m.	14.1	1.0305	88.25	11.75	.53	3.38	.37	.076	4.63	2.95	20.36	37.72	234.8	34.40	73
3	a. m.	15.2	1.0305	88.79	11.21	.50	3.19	.37	.054	5.05	2.71	21.19	40.07	235.7	32.95	58
	p. m.	13.2	1.0310	88.41	11.59	.54	3.45	.38	.061	4.61	3.34	18.93	34.28	230.2	33.90	67
4	a. m.	14.4	1.0300	88.60	11.40	.52	3.32	.40	.057	4.53	3.26	19.68	40.84	239.1	33.30	61
	p. m.	13.1	1.0306	88.74	11.26	.52	3.32	.39	.057	4.64	2.88	20.95	36.81	228.2	33.30	72
5	a. m.	14.0	1.0294	88.39	11.61	.51	3.25	.38	.062	4.53	3.49					85
	p. m.	13.3	1.0306	88.51	11.49	.52	3.32	.38	.060	4.61	3.41	19.24	45.04	228.7	33.75	86
6	a. m.	14.0	1.0299	88.75	11.25	.51	3.25	.36	.061	4.50	3.67	18.83	44.58	229.8	33.68	62
	p. m.	13.9	1.0304	88.60	11.40	.52	3.32	.40	.062	4.60	3.65	19.06	45.00	234.0	34.00	88
7	a. m.	14.3	1.0297	89.24	10.76	.53	3.38	.35	.062	4.49	3.15	21.56	41.46	238.8	33.05	91
	p. m.	14.5	1.0300	88.59	11.41	.52	3.32	.38	.068	4.48	3.19	19.23	44.41	226.1	33.65	70
8	a. m.	14.8	1.0294	88.80	11.20	.53	3.38	.34	.057	4.59	3.49	20.88	43.21	250.7	33.30	81
	p. m.	13.6	1.0306	88.91	11.09	.52	3.32	.36	.059	4.59	3.05	19.86	40.65	236.9	33.25	69
9	a. m.	14.3	1.0293	88.66	11.34	.53	3.38	.37	.059	4.55	3.19	23.65	40.57	242.4	33.65	56
	p. m.	12.6	1.0304	88.64	11.36	.53	3.38	.38	.071	4.56	3.15	19.72	44.84	230.0	33.40	72
10	a. m.	13.4	1.0294	88.81	11.19	.50	3.19	.38	.060	4.48	3.23	19.96	39.51	233.2	34.30	67
	p. m.	14.1	1.0305	88.85	11.15	.52	3.32	.38	.052	4.53	3.05	19.37	43.23	230.1	33.20	75
11	a. m.	14.8	1.0290	88.88	11.12	.51	3.25	.34	.062	4.38	3.09	20.62	43.01	237.4	33.10	58
	p. m.	13.9	1.0304	88.84	11.16	.52	3.32	.37	.054	4.34	2.88	19.10	44.57	233.9	33.10	57
12	a. m.	14.5	1.0301	88.60	11.40	.52	3.32	.37	.059	4.66	3.31	19.92	43.18	234.9	33.05	62
	p. m.	13.5	1.0301	89.16	10.84	.50	3.19	.37	.061	4.29	3.06	19.20	44.90	233.6	33.40	52
13	a. m.	14.3	1.0296	89.36	10.64	.49	3.13	.36	.061	4.50	2.98	19.20	41.89	232.7	33.75	65
	p. m.	14.0	1.0301	89.06	10.94	.52	3.32	.37	.057	4.61	3.26	18.42	43.28	229.9	33.55	54
14	a. m.	14.3	1.0296	89.12	10.88	.49	3.13	.36	.071	4.33	2.94	21.45	41.66	235.7	33.80	57
	p. m.	13.3	1.0301	88.66	11.34	.52	3.32	.37	.059	4.49	3.40	20.13	42.60	233.6	32.95	51
15	a. m.	14.3	1.0303	88.94	11.06	.53	3.38	.38	.067	4.71	3.06	19.65	42.60	232.0	33.25	60
	p. m.	13.1	1.0306	88.85	11.15	.53	3.38	.38	.057	4.59	3.21	18.39	45.37	237.3	34.00	73

TABLE I.—*Showing variation from milking to milking—Detailed analyses of milk from cows milked twice daily*—Continued.

COW NO. 320.

Date of milking.		Yield of milk.	Specific gravity of milk.	Water.	Total solids.	Total nitrogen.	Total protein (N. x 6.38).	Casein nitrogen.	Albumin nitrogen.	Sugar.	Fat.	Reichert-Meissl number.	Iodin number.	Saponification number.	Melting point of fat.	Relative size of fat globules.
1909.		*Pounds.*		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*				° *C.*	
Jan. 23	a. m.	10.6	1.0310	85.53	14.47	0.55	3.51	0.45	0.043	4.81	5.54	26.15	23.19	234.3	35.45	418
	p. m.	10.0	1.0321	86.55	13.45	.52	3.32	.42	.046	5.18	4.70	27.73	23.30	235.6	35.20	450
24	a. m.	10.5	1.0335	85.47	14.53	.56	3.57	.45	.049	5.40	5.39	26.00	23.34	240.0	35.15	481
	p. m.	10.0	1.0321	86.30	13.70	.54	3.45	.43	.048	4.94	4.96	26.61	24.04	238.4	35.35	274
25	a. m.	9.8	1.0322	85.97	14.03	.57	3.64	.45	.059	4.66	5.11	23.77	26.35	234.4	35.20	365
	p. m.	8.5	1.0327	85.89	14.11	.58	3.70	.45	.044	4.58	5.10	24.65	28.27	232.3	34.80	317
26	a. m.	10.1	1.0330	85.44	14.56	.56	3.57	.46	.052	5.00	5.40	26.84	24.56	233.7	35.50	424
	p. m.	9.1	1.0331	86.48	13.52	.56	3.57	.45	.041	4.78	4.62	25.24	25.20	234.5	35.70	293
27	a. m.	10.4	1.0331	85.32	14.68	.56	3.57	.46	.058	5.08	5.45	26.94	24.62	237.8	35.20	347
	p. m.	8.9	1.0328	86.33	13.67	.57	3.64	.44	.059	4.80	4.65	27.15	23.62	240.3	35.70	259
28	a. m.	10.4	1.0316	85.90	14.10	.55	3.51	.42	.054	4.55	5.33	28.01	22.92	240.8	34.85	389
	p. m.	10.4	1.0312	86.61	13.39	.54	3.45	.44	.051	4.78	4.90	27.08	23.01	235.1	34.55	402
29	a. m.	9.5	1.0335	85.20	14.80	.57	3.64	.47	.047	5.05	5.76	27.89	23.73	235.9	34.85	335
	p. m.	10.2	1.0327	85.78	14.22	.54	3.45	.42	.048	4.70	5.19	26.58	24.48	235.1	34.80	352
30	a. m.	10.4	1.0325	85.26	14.74	.55	3.51	.42	.057	5.11	5.64	26.62	23.29	235.1	35.95	284
	p. m.	8.7	1.0335	85.47	14.53	.58	3.70	.47	.052	5.14	5.25	26.30	24.00	234.2	35.30	448
31	a. m.	10.3	1.0334	84.43	15.57	.60	3.83	.43	.066	4.66	6.30	26.47	24.08	234.6	35.65	324
	p. m.	7.9	1.0326	85.51	14.49	.57	3.64	.43	.054	4.88	5.32	22.97	26.11	234.5	35.35	256
Feb. 1	a. m.	9.3	1.0332	84.29	15.71	.57	3.64	.45	.067	4.75	6.31	......	......	......	......	532
	p. m.	8.0	1.0338	85.80	14.20	.57	3.64	.47	.053	5.03	4.88	24.86	24.20	232.8	35.65	313
2	a. m.	10.2	1.0333	85.08	14.92	.60	3.83	.46	.052	5.50	5.52	26.21	22.53	235.5	35.85	303
	p. m.	8.8	1.0326	86.54	13.46	.56	3.57	.44	.053	4.66	4.56	24.83	23.66	233.9	35.65	292
3	a. m.	9.7	1.0340	84.82	15.18	.59	3.76	.45	.060	5.46	5.80	25.94	22.42	235.7	35.65	410
	p. m.	10.0	1.0317	86.56	13.44	.54	3.45	.41	.049	4.54	4.60	24.39	23.24	234.9	35.80	346
4	a. m.	9.7	1.0328	84.75	15.25	.56	3.57	.42	.067	4.73	5.90	25.28	21.98	233.2	35.95	417
	p. m.	9.2	1.0318	86.05	13.95	.54	3.45	.43	.052	4.81	5.30	25.21	22.70	235.3	36.10	274
5	a. m.	10.5	1.0320	85.70	14.30	.57	3.64	.45	.043	5.13	5.50	25.09	23.69	234.3	35.65	187
	p. m.	9.0	1.0326	85.61	14.39	.55	3.51	.43	.057	4.88	5.58	24.17	27.62	232.1	35.65	172

COW NO. 400.

1909.																
Jan. 23	a. m.	10.6	1.0335	86.54	13.46	0.54	3.45	0.44	0.044	5.25	4.16	25.68	29.25	232.5	33.85	456
	p. m.	9.5	1.0343	86.96	13.04	.56	3.57	.44	.051	5.39	3.66	26.43	31.19	233.1	34.05	457
24	a. m.	10.2	1.0348	86.29	13.71	.56	3.57	.44	.052	5.46	4.23	28.31	29.31	224.2	34.25	505
	p. m.	9.7	1.0342	86.51	13.49	.57	3.64	.45	.051	5.50	4.12	25.48	30.79	234.1	34.05	345
25	a. m.	10.2	1.0342	86.20	13.80	.55	3.51	.44	.057	5.48	4.44	28.81	29.66	234.4	33.80	540
	p. m.	9.4	....	....	....	....	....	....	....	....	....	....	....	....	....	....
26	a. m.	10.5	1.0341	86.12	13.88	.55	3.51	.46	.054	5.50	4.42	28.16	29.29	233.1	33.85	355
	p. m.	9.7	1.0348	86.86	13.14	.57	3.64	.46	.052	5.40	3.78	27.12	31.91	234.8	33.65	415
27	a. m.	10.0	1.0344	86.32	13.68	.56	3.57	.46	.057	5.65	4.22	26.16	30.41	235.5	33.80	445
	p. m.	9.6	1.0340	86.88	13.12	.54	3.45	.43	.056	5.23	3.83	26.77	31.27	233.7	34.20	608
28	a. m.	10.1	1.0345	86.46	13.54	.55	3.51	.45	.054	5.35	4.13	26.60	30.65	229.7	34.30	612
	p. m.	9.6	1.0351	86.54	13.46	.57	3.64	.46	.056	5.40	3.96	25.49	31.64	230.4	33.95	477
29	a. m.	10.4	1.0347	86.07	13.93	.55	3.51	.46	.056	5.05	4.48	26.44	30.39	233.3	34.05	687
	p. m.	8.9	1.0344	86.96	13.04	.57	3.64	.43	.079	5.36	3.59	25.75	30.77	229.5	33.85	260
30	a. m.	11.0	1.0332	86.89	13.11	.56	3.57	.43	.057	5.50	3.89	26.21	30.52	229.6	34.30	243
	p. m.	8.5	1.0360	86.28	13.72	.60	3.83	.47	.045	5.46	3.86	27.28	30.69	233.8	33.45	243
31	a. m.	10.2	1.0352	85.73	14.27	.60	3.83	.47	.062	5.68	4.54	26.06	30.50	233.1	33.60	333
	p. m.	8.8	1.0346	86.23	13.77	.58	3.70	.45	.058	5.04	4.12	23.45	30.22	230.4	33.95	366
Feb 1	a. m.	9.2	1.0350	86.27	13.73	.57	3.64	.46	.061	5.53	4.15	25.26	28.77	233.5	34.40	357
	p. m.	9.2	1.0341	86.43	13.57	.58	3.70	.46	.062	5.70	4.07	26.98	30.86	233.7	33.90	337
2	a. m.	9.6	1.0335	85.39	14.61	.58	3.70	.46	.059	5.51	5.29	25.85	28.72	230.9	34.25	410
	p. m.	9.5	1.0342	87.07	12.93	.58	3.70	.45	.059	5.19	3.46	25.80	29.87	233.8	34.05	481
3	a. m.	9.8	1.0345	86.80	13.20	.56	3.57	.43	.069	5.33	3.74	25.98	28.87	232.8	33.90	447
	p. m.	9.7	1.0331	87.24	12.76	.54	3.45	.44	.061	4.83	3.68	23.63	31.32	231.2	33.65	564
4	a. m.	9.9	1.0341	86.73	13.27	.55	3.51	.44	.059	5.16	3.88	24.93	28.99	232.8	33.75	297
	p. m.	9.7	1.0340	86.75	13.25	.55	3.51	.42	.054	5.53	4.09	26.19	31.18	234.3	33.60	218
5	a. m.	10.1	1.0344	86.37	13.63	.55	3.51	.45	.062	5.34	4.14	27.11	28.99	233.5	33.65	193
	p. m.	8.8	1.0338	86.78	13.22	.55	3.51	.42	.051	5.18	4.16	26.12	30.88	232.3	33.65	226

TABLE II.—*Variation from milking to milking of cow No. 209, milked three times daily.*

Date of milking.	Yield of milk.	Specific gravity of milk.	Water.	Total solids.	Ash.	Total nitrogen.	Casein nitrogen.	Sugar.	Fat.	Reichert-Meissl number.	Iodin number.	Saponification number.	Melting point of fat.	Relative size of fat globules.	Color of fat.		
															Yellow.	Red.	Light.
1910.	*Pounds.*		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*				° *C.*				
Feb. 28	23.6	1.0300	90.01	9.99	0.76	0.43	0.30	4.65	2.24	30.43	31.91	231.8	32.47	83	19	1.7	0.2
	19.2	1.0282	89.47	10.53	.68	.44	.31	4.50	2.89	30.20	33.22	230.8	31.57	73	20	1.7	.2
	14.7	1.0299	89.14	10.86	.73	.44	....	4.69	3.19	29.04	33.52	231.2	31.57	75	22	1.7	.2
Mar. 1	24.2	1.0305	89.74	10.26	.75	.44	.33	4.72	2.82	29.04	31.79	232.1	32.10	82	20	1.7	.2
	18.5	1.0290	88.91	11.09	.73	.43	.30	4.48	3.60	29.14	32.56	231.5	32.57	62	34	2.0	.2
	15.4	1.0290	88.67	11.33	.72	.43	.30	4.80	3.63	28.14	32.21	229.9	32.33	77	28	1.8	.2
2	24.5	1.0300	89.74	10.26	.72	.43	.31	4.81	2.38	28.81	30.73	231.2	32.47	73	21	1.7	.2
	21.2	1.0294	89.18	10.82	.71	.43	.31	4.55	3.29	29.52	32.10	230.6	31.90	64	19	1.7	.2
	15.3	1.0294	89.11	10.89	.73	.44	.31	4.61	3.27	29.36	32.21	231.1	32.10	77	25	1.7	.2
3	24.1	1.0302	89.72	10.28	.72	.43	.32	4.49	2.43	29.25	31.90	231.0	31.77	56	26	1.7	.2
	18.2	1.0286	89.26	10.74	.69	.41	.31	4.56	3.19	29.08	34.20	229.4	31.80	64	24	1.7	.2
	14.6	1.0295	89.08	10.92	.71	.43	.31	4.75	3.05	29.11	34.24	229.0	33.30	60	22	1.7	.2
4	24.0	1.0303	89.74	10.26	.74	.41	.30	4.78	2.65	29.32	31.76	230.2	33.27	74	21	1.7	.2
	18.3	....	....	....	....	....	....	....	....	28.83	32.90	229.8	32.50	70	20	1.7	.2
	15.5	1.0283	89.62	10.38	.71	.43	.31	4.51	2.96	28.25	33.29	227.4	32.33	70	17	1.7	.2
5	22.3	1.0301	89.68	10.32	.76	.40	.31	4.68	2.50	29.83	32.00	230.5	32.73	61	25	1.7	.2
	19.0	1.0290	89.37	10.63	.75	.42	.29	4.46	2.98	29.83	32.75	230.2	32.90	67	22	1.7	.2
	14.4	1.0317	88.22	11.78	.75	.50	.36	5.00	3.22	27.69	34.49	226.6	34.27	77	19	1.7	.2
6	23.3	1.0312	89.59	10.41	.69	.44	.31	5.23	2.30	29.74	32.16	231.0	31.97	58	21	1.7	.2
	19.7	1.0278	89.11	10.89	.69	.41	.29	4.63	3.60	29.10	33.36	229.3	33.43	67	27	2.2	.2
	14.2	1.0284	89.02	10.98	.68	.42	.29	4.73	3.45	28.64	34.06	228.2	33.93	77	22	1.7	.2

TABLE III.—*Variations from milking to milking of cow No. 207 milked four times daily.*

Date of milking.		Yield of milk.	Specific gravity of milk.	Water.	Total solids.	Ash.	Total nitrogen.	Total protein (N. x 6.38).	Casein nitrogen.	Sugar.	Fat.	Reichert-Meissl number.	Iodin number.	Saponification number.	Melting point of fat.	Relative size of fat globules.	Color of fat.		
																	Red.	Yellow.	Light.
1910.		*Lbs.*		*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*				*° C.*				
Feb. 1	4 a. m.	29.5	1.0296	89.94	10.06	0.72	0.43	2.74	0.31	4.53	2.25	34.28	38.52	227.9	34.00	239	1.7	33	0.2
	10 a. m.	25.6	1.0274	88.64	11.36	.70	.41	2.62	.29	4.34	3.05	34.00	39.12	226.9	34.52	185	1.6	28	.2
	4 p. m.	24.1	1.0298	89.95	10.05	.75	.41	2.62	.30	4.53	2.36	33.62	38.95	228.3	33.78	141	1.7	30	.2
	10 p. m.	25.5	1.0291	90.40	9.60	.72	.41	2.62	.29	4.46	2.12	33.13	39.55	226.9	33.87	213	1.7	30	.2
2	4 a. m.	28.3	1.0299	90.37	9.63	.69	.43	2.74	.30	4.69	1.67	30.37	40.50	226.3	34.97	99	1.7	28	.2
	10 a. m.	21.7	1.0299	....	....	.73	.42	2.70	.30	4.46	....	30.47	40.40	225.5	34.03	....	1.7	24	.2
	4 p. m.	28.4	1.0295	90.22	9.78	.72	.41	2.62	.27	4.55	2.29	33.83	38.28	228.8	33.70	162	1.7	31	.2
	10 p. m.	23.0	1.0284	89.22	10.78	.72	.39	2.49	.27	4.66	3.23	32.01	41.19	228.0	34.45	243	1.7	25	.2
6	4 a. m.	31.9	1.0295	90.77	9.23	.72	.39	2.49	.29	4.46	1.68	31.95	40.59	228.3	33.93	119	1.7	25	.2
	10 a. m.	27.1	1.0287	89.33	10.67	.72	.40	2.55	.28	4.66	3.10	33.52	40.60	231.0	33.70	178	1.7	29	.2
	4 p. m.	24.2	1.0296	89.92	10.08	.72	.40	2.55	.28	4.71	2.52	31.38	41.70	227.8	33.97	161	1.7	25	.2
	10 p. m.	27.0	1.0275	91.15	8.85	.68	.36	2.30	.24	4.25	1.88	32.96	41.62	229.8	33.40	252	1.7	28	.2
15	4 a. m.	22.8	1.0306	90.35	9.65	.73	.39	2.49	.19	4.70	1.98	27.15	40.59	226.4	34.20	201	2.0	45	.2
	10 a. m.	22.3	1.0279	90.86	9.14	.71	.38	2.42	.25	4.53	3.56	27.74	41.97	223.3	33.98	162	1.7	43	.2
	4 p. m.	19.0	1.0305	89.51	10.49	.73	.41	2.62	.27	4.71	2.78	27.81	42.16	223.8	34.03	171	1.7	43	.2
	10 p. m.	18.6	1.0295	90.03	9.97	.63	.37	2.36	.24	4.52	2.45	27.82	42.29	223.7	34.10	295	1.7	43	.2
16	4 a. m.	28.0	1.0306	89.46	10.54	.76	.41	2.62	.27	4.65	2.75	28.31	42.95	223.3	34.23	142	1.7	40	.2
	10 a. m.	18.4	....	88.15	11.85	.73	....	....	.26	4.41	4.15	28.02	43.90	223.4	33.73	138	1.7	40	.2
	4 p. m.	20.3	1.0301	89.47	10.53	.75	.43	2.74	.25	4.53	2.62	27.46	44.23	223.5	33.47	132	1.7	43	.2
	10 p. m.	17.5	1.0289	88.92	11.08	.73	.40	2.55	.25	4.61	3.31	27.48	44.34	223.1	34.07	118	1.7	42	.2

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THE ROUNDWORMS OF DOMESTIC SWINE,

WITH SPECIAL REFERENCE TO TWO SPECIES PARASITIC IN THE STOMACH.

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THE ROUNDWORMS OF DOMESTIC SWINE, WITH SPECIAL REFERENCE TO TWO SPECIES PARASITIC IN THE STOMACH.

SUMMARY.

Two species of roundworms belonging to the family Filariidæ, of particular interest to helminthologists and veterinarians on account of their wide distribution and frequency of occurrence in American swine and the possibility that they may cause serious injury to their host, are given special consideration in this paper.

One of these species, identified as *Spiroptera strongylina*, has recently been placed in a new genus, *Arduenna*, of which it is the type, and several errors regarding the anatomy of this parasite have been corrected. Another species, *Arduenna dentata*, has been found in China associated with *Arduenna strongylina*, and although not yet reported in American swine is mentioned in this connection, as further investigation may reveal its presence in this country.

Arduenna strongylina is much more common in American swine than it is said to be in European swine, and has been found abundantly in the slaughterhouses at St. Louis, Chicago, South Omaha, and Kansas City, and has also been collected at Benning, D. C., and Bethesda, Md.

Specimens of hogs' stomachs received from Chicago showed the worms deeply fastened in the submucosa or embedded in necrotic tissue near which were deep ulcers. The condition suggested infection with *Bacillus necrophorus*, the inoculation of which might easily result from the burrowing of the worms; however, owing to the sterile condition of the specimens received, this could not be satisfactorily demonstrated. A similar diseased condition of the stomachs of hogs in Europe is attributed by Von Rátz (1899d)[1] to infection with *Arduenna strongylina*. Under the circumstances the worm should be regarded with grave suspicion, and general prophylactic measures for the prevention of the spread of infection are suggested.

Commonly associated with *Arduenna strongylina* in this country is another worm, identified as *Physocephalus sexalatus*, first described by Molin (1860b) from specimens from the peccary (*Dicotyles labiatus*) from Brazil; also found by him associated with *Arduenna strongylina* from the wild boar in Germany. It is also reported by Von Linstow (1879b) (who apparently mistook this species for *Arduenna strongylina*) and Piana (1897e), from Europe, and by Railliet and Henry (1911b), from Madagascar and Indo-China, in the former case associated with a severe gastritis. Seurat (1912) has recently reported this species from the ass and dromedary in Algeria, but his statements would seem to require confirmation.

According to the writer's experience, *Physocephalus sexalatus* is almost as widely distributed as *Arduenna strongylina*, since out of eight lots of specimens of the latter species, specimens of *Physocephalus sexalatus* were found in all but one. In a mixed infection, however, it has never been found as abundantly as *Arduenna strongylina*. This worm has apparently the same habit of injuring the mucosa as has *Arduenna strongylina*, as both species were found in the same necrotic tissue in a hog's stomach. It must therefore be considered only less dangerous because it is less abundant, and should be subject to the same treatment suggested for infestation with *Arduenna strongylina*.

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[1] References to literature will be found in bibliography at end of bulletin.

Nothing is known in regard to the life cycle of these parasites, but their wide distribution and frequency of occurrence suggest a simple life history without an intermediate host. The fact that the eggshells of both species are relatively thick would seem to indicate that the embryos are not liberated until the shell is dissolved by the gastric juice of the host. From the fact that the embryos are fairly well developed before oviposition, it may be inferred that the eggs require but a short period of incubation.

Following the discussion of the two species is a key for use in the identification of roundworms parasitic in swine; also a list of these parasites classified according to their zoological position.

INTRODUCTION.

Nematodes occurring in the stomach are commonly present among swine in the United States. These have usually been considered by veterinarians, pathologists, and others who have had occasion to mention them as belonging to the species *Spiroptera strongylina* Rudolphi, 1819, although some have expressed a doubt as to the correctness of the identification. In addition to the forms which have been identified as *Spiroptera strongylina*, Hassall and Stiles (1892a) have described a species named by them *Strongylus rubidus*, and which has since been collected from domestic swine in Europe.

Recently a zoological study of specimens of nematodes in the helminthological collection of the Bureau of Animal Industry, collected from the stomachs of hogs in various parts of the United States, was undertaken by the present writer, largely as a result of reports from inspectors relative to the prevalence of nematodes in the stomachs of swine, Drs. J. J. Brougham and T. B. Pote, of the St. Louis station, having been among the first in the Federal service to give attention to the subject from the standpoint of meat inspection. As a result of this study and of a comparison of these specimens with specimens of *Spiroptera strongylina* received from Europe, the conclusion has been reached that in several particulars the descriptions of *Spiroptera strongylina* commonly given by European writers are in error, and that the forms commonly identified as *Spiroptera strongylina* represent two distinct species, one of them *Spiroptera strongylina*, the other corresponding to *Physocephalus sexalatus* (Molin, 1860) Diesing, 1861, hitherto considered a rare parasite and until recently reported only once for domestic swine.

According to Stiles and Hassall (1905b), the genus *Spiroptera* is preempted by the genus *Acuaria* Bremser, 1811, whose type is *anthuris*. This species is also the type of *Dispharagus* Dujardin, 1845, a genus based largely on certain nematodes of birds and not found in mammals. According to this ruling, the genus *Acuaria* is confined to certain parasites of birds and fishes characterized by a differentiation in the structure of the esophagus. As *Spiroptera strongylina* does not conform to the type of *Acuaria* or the characteristics of the genus, a new genus to include these forms is necessary. This deficiency has been supplied by the creation of a new genus, *Arduenna*, by Railliet and Henry (1911), *Spiroptera strongylina* being taken as the type. Both *Arduenna* and *Physocephalus*, together with *Simondsia paradoxa*, belong in the family Filariidæ,[1] and are included by Railliet and Henry (1911b) in the new subfamily Arduenninæ.

FAMILY FILARIIDÆ, CLAUS, 1885.

FAMILY DIAGNOSIS.—Nematoda: Body long, filiform. Mouth surrounded with papillæ, or provided with two lips. Esophagus slender, without posterior bulb. Males with a single spicule or with two unequal spicules. Females with two ovaries; vulva usually in front of the middle of the body. Usually ovoviviparous. Development in many cases requires an intermediate host.

TYPE GENUS.—*Filaria* Müller, 1787.

Subfamily ARDUENNINÆ Railliet and Henry, 1911.

SUBFAMILY DIAGNOSIS.—Filariidæ: Mouth with two lateral lips leading into a pharynx marked with cuticular ridges in the form of spirals or rings. Spicules unequal, the longer several times the length of the shorter. Four pairs of preanal papillæ. Eggs containing embryos when oviposited.

TYPE GENUS.—*Arduenna* Railliet and Henry, 1911.

Genus ARDUENNA Railliet and Henry, 1911.

GENERIC DIAGNOSIS.—Filariidæ: Body subcylindrical, attenuated anteriorly, posteriorly somewhat broader, usually curved in a semicircle, marked by a narrow, longitudinal cuticular wing on the left side, extending nearly the length of the body. Cuticle densely striated transversely. Mouth with two lateral lips, each lip with three lobes, leading into a small buccal capsule containing two lateral teeth, and followed by a cylindrical pharynx marked with cuticular ridges forming a series of spirals. Esophagus continuous, gradually broadening posteriorly and occupying from one-fourth to one-third of the body length. Caudal end of the male curved in a single turn. Bursa asymmetrical, the right bursal wing being broader than the left wing, furnished with five pairs of stalked papillæ asymmetrically arranged, of which one pair is preanal, three pairs are adanal, and the fourth pair is postanal. Bursal membrane marked with longitudinal and transverse striæ, giving it a wrinkled appearance. Anus surrounded by a cuticular thickening, serrated on the outside edge. Spicules long and very unequal, the longer five to seven times the length of the shorter. Vulva anterior of the middle of the body. Eggs with thick shells containing embryos at the moment of oviposition. Parasitic in the stomachs of Suidæ.

TYPE SPECIES: *Arduenna strongylina* (Rudolphi, 1819), Railliet and Henry, 1911.

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[1] Diesing (1861a) proposed the family name Spiruridea for a group of nematodes distinguished from *Filaria* by the curl or spiral twist of the tail of the male. This family is not accepted by most recent writers on the ground that it is not based on sufficiently characteristic morphological features, and that the name does not conform to the rules of zoological nomenclature. Oerley (1885a), Leiper (1908), and Railliet and Henry (1911b) use the name Spiruridæ, apparently modifying Diesing's (1861a) family name Spiruridea to conform to the present zoological nomenclature. The family name Spiropteridæ is proposed by Leiper (1911).

Owing, however, to the apparent invalidity of the name Spiroptera, the present writer prefers not to use either the family name Spiruridæ or Spiropteridæ, and although it is evident that the genera *Arduenna* and *Physocephalus*, and other genera as well, will ultimately be separated from the Filariidæ, it is not considered desirable to attempt such a revision until a more careful study has been made of the various species involved. In the present paper, therefore, *Arduenna* and *Physocephalus* are retained in the family Filariidæ but included under the subfamily Arduenninæ, Railliet and Henry, 1911.

Arduenna strongylina (Rudolphi, 1819) Railliet and Henry, 1911.

1819: *Spiroptera strongylina* Rudolphi, 1819a, p. 23.
1819: *Spiropteru strongylina* Rudolphi, 1819a, p. 237. Misprint for *Spiroptera.*
1828: *Spiroptera strongyliformis* De Blainville, 1828a, p. 546.
1866: *Filaria strongylina* (Rudolphi) Schneider, 1866a, p. 101.

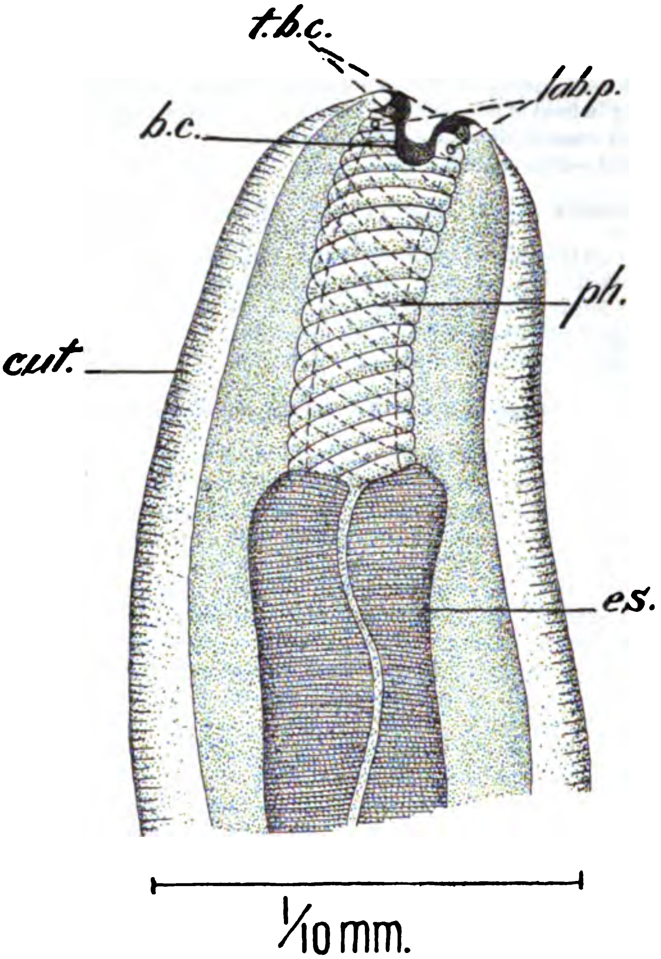

FIG. 1.—*Arduenna strongylina.* Median view of cephalic end. *b. c.*, buccal capsule; *cut.*, cuticle; *es.*, esophagus; *lab. p.*, labial papillæ; *ph.*, pharynx; *t. b. c.*, teeth of the buccal capsule. × 560. (Original.)

SPECIFIC DIAGNOSIS.—Cuticule densely striated transversely, increasing in thickness toward the anterior extremity, which is furnished with two cervical papillæ placed asymmetrically, the left being about 190 μ and the right 390 μ from the anterior extremity. Beginning at a point 280 μ from the anterior end on the left side, a narrow cuticular wing gradually increasing to a maximum breadth of 35 μ extends to a point about 2 mm. from the posterior extremity. Mouth 44 to 45 μ in diameter with two lateral lips each with three lobes, having a small round papilla at the base of each of the lobes. Just below the lips and projecting into the mouth cavity are two chitinous teeth, formed by a prolongation of the wall of the pharynx (fig. 1). The pharynx, 29 μ wide by 83 to 98 μ long, is marked on the inside by a series of chitinous ridges in the form of continuous spirals (or a multiple spiral), all running in the same direction and appearing like the threads of a quadruple screw.

Esophagus 3.1 to 3.7 mm. long, or about one-fourth of the body length, and 117 to 127 μ wide at its widest part near the base. Nerve ring 0.35 mm. and excretory pore 0.48 mm. from the anterior end.

Male 10 to 15 mm. long, averages about 13 mm. in length; 301 to 387 μ wide at the widest part just above the bursa. The bursal wings extend from a point about 1.2 mm. from the caudal extremity to the tip, the body ending in a blunt point. Bursal wings irregularly ovate, asymmetrical, the right bursal wing being about twice as wide as the left wing. The bursa contains 5 pairs of stalked papillæ asymmetrically arranged, of which 4 pairs are preanal and the last pair is postanal. Bursa marked with fine longitudinal striæ, increasing in density toward its base (fig. 2). Spicules two, grooved on the ventral surface, the left spicule 2.24 to 2.95 mm. long, very slender, ending in a fine point and presenting a slightly concave surface near the tip on the dorsal side. The right spicule (about one-fifth of the length of the left spicule) is stouter and blunter at the point, measuring 10 μ at its base, or nearly twice the width of the base of the long spicule, and is 457 to 619 μ long (fig. 3). Anus 155 to 200 μ from the posterior end and surrounded on the posterior and left side by a cuticular thickening (circumanal ring), the outer edge of which is serrated.

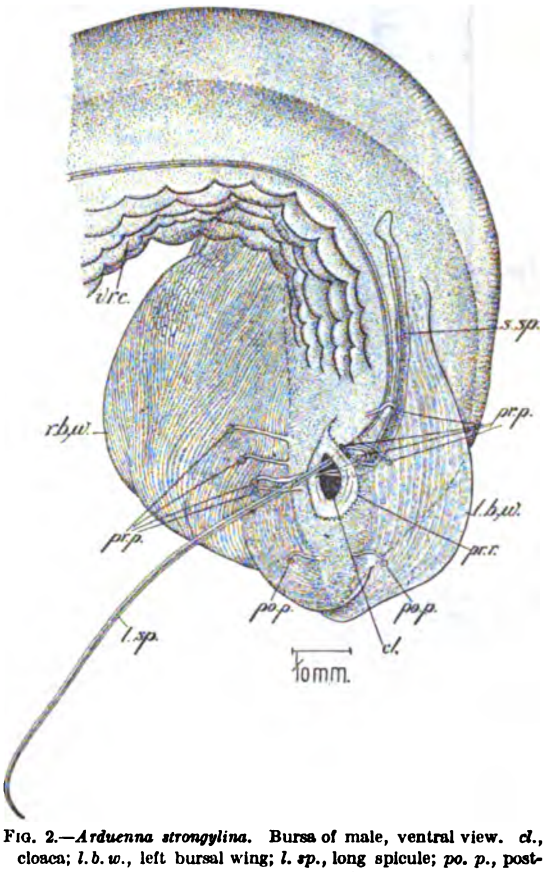

FIG. 2.—*Arduenna strongylina.* Bursa of male, ventral view. *cl.*, cloaca; *l. b. w.*, left bursal wing; *l. sp.*, long spicule; *po. p.*, postanal papillæ; *pr. p.*, preanal papillæ; *r. b. w.*, right bursal wing; *s. sp.*, short spicule; *v. r. c.*, ventral ridge of the cuticle. × 75. (Original.)

Female 16 to 22 mm. long, 263 to 420 μ wide; average maximum width 368 μ, at a point about one-third of the distance from the head to the caudal end. For the next third of the distance the width remains constant except for a slight constriction in the region of the vulva. Beginning at a point about two-thirds of the distance from the head to the caudal end, where one of the uteri turns back on itself, the width gradually diminishes and then abruptly decreases a short distance in front of the anus. Anus 215 to 275 μ from the caudal tip (fig. 4).

The orbicular naked vulva opening near the left side close to the lateral cuticular wing is slightly anterior of the middle of the body, dividing the worm anteriorly and posteriorly in the ratio 5 : 6. Vagina uniform, about 49 μ in diameter, 1.7 mm. long, extending in a generally posterior direction, joining the uteri at a point about 1.1 mm. from the vulva measured in a straight line (fig. 5).

Eggs oval, 34 to 39 μ long by 20 μ wide, with thick shells. Embryos well developed in the shell before oviposition (fig. 6).

Hosts.—Domestic hog (*Sus scrofa domestica*), wild boar (*Sus scrofa fera*).

Location.—Stomach and small intestine.

Localities collected.—United States: Bethesda, Md.; Benning, D. C.; Chicago, Ill.; South Omaha, Nebr.; St. Louis, Mo.; Kansas City, Mo.; Denver, Colo.; Brazos County, Tex. Europe: Germany, France, Hungary, Roumania, Italy. Asia: Turkestan, Indo-China.

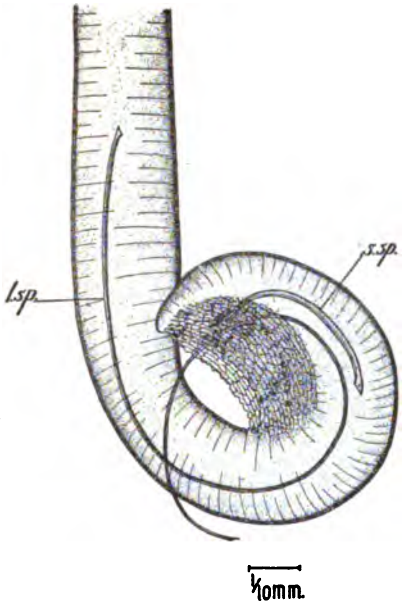

FIG. 3.—*Arduenna strongylina.* Posterior end of body of male, viewed from right side. *l. sp.*, long spicule; *s. sp.*, short spicule. × 65. (Original.)

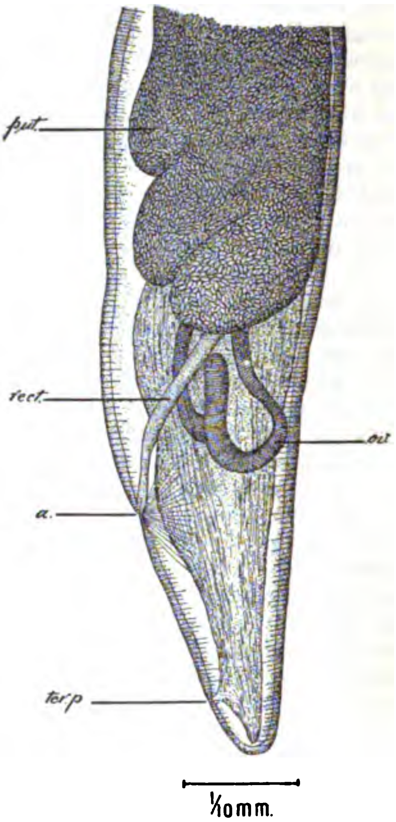

FIG. 4.—*Arduenna strongylina.* Posterior end of body of female, viewed from left side. *a.*, anus; *ov.*, ovary; *p. ut.*, posterior uterus; *rect.*, rectum; *ter. p.*, terminal papilla. × 150. (Original.)

The number of spiral ridges in the pharynx seems to vary both with the sex and among different individuals of the same sex. In the specimen figured, a female (fig. 1), there are four separate ridges, the usual number for females. Males have, as a rule, but three spirals. Railliet and Henry (1911b) mention 2 to 3 spiral ridges for males and 4 to 5 for females.

The retractor muscles controlling the movements of the right spicule are a pair of narrow lamellar strips, longitudinally finely striated, asymmetrically twisted in the center, attached at the posterior end to the spicule and at the anterior end to the ventral side of the body. The muscles are fully as long as the spicule they control (fig. 7).

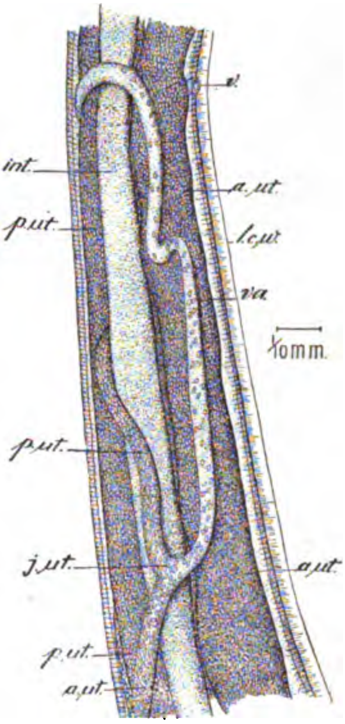

FIG. 5.—*Arduenna strongylina.* Ventral view of middle of body of female. *a. ut.*, anterior uterus; *int.*, intestine; *j. ut.*, junction of the uteri; *l. c. w.*, lateral cuticular wing; *p. ut.*, posterior uterus; *v.* vulva; *va.*, vagina. × 58. (Original.)

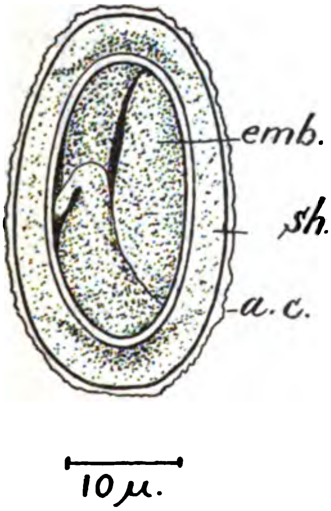

FIG. 6.—*Arduenna strongylina.* Lateral view of egg removed from a ruptured uterus. *a. c.*, albuminous covering; *emb.*, embryo; *sh.*, shell. × 1,450. (Original.)

The vas deferens appears as a tube of darker color than the intestine, about 130 µ in its average diameter, and extending throughout the posterior third of the body length. About 450 µ from its terminus it rapidly diminishes in diameter toward the cloaca, and in the specimen figured (fig. 8) is bent in the shape of the letter S. The seminal tube is very long and convoluted, resembling in appearance the ovaries of the female. Near the posterior end of the male the intestine, 123 µ wide, first crosses above the vas deferens toward the dorsum, then curves underneath as it approaches the cloaca. Its terminus was obscured by the organs lying above it. In the specimen figured (fig. 8) the sheath of the right spicule is much contracted and appears as a dark-colored bag too short to contain the entire spicule and within which the base of the spicule may be dimly seen. The ventral surface of the male in the region immediately anterior of the bursa is furnished with 7 to 8 parallel longitudinal cuticular ridges divided transversely into serrations. This structure, modifications of which are seen in many nematodes, including *Physocephalus sexalatus*, probably assists in maintaining the position of the male in copulation, as suggested by Ciurea (1911). The anus is partially encircled by a rim of thickened cuticle, the outer edge of which is ornamented with serrated cuticular projections. This cuticular thickening extends along the posterior and left sides of the anus, forming about two-thirds of a complete circle. The thickened cuticle seems to project downward into the body (fig. 2).

Ciurea (1911) depicts 10 tactile papillæ located on the ventral surface of the body of the male, close to the tip of the tail. These could not be seen in the specimens studied by the writer. The rectum (fig. 4) of the female is about 80 μ in maximum width and nearly as long as the distance from the anus to the tip of the tail. In the region immediately posterior of the anus several fine lines can be seen beneath the cuticle, converging toward the base of the anus. These are probably muscle fibers controlling the rectum, and are seen in the females of many nematodes. A pair of papillæ close to the tip of the tail extend laterally to the edges of the caudal cuticle on the ventral side.

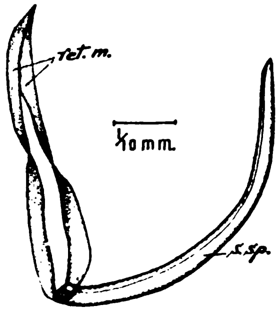

FIG. 7.—*Arduenna strongylina.* Short spicule with retractor muscles viewed from right side. *ret. m.*, retractor muscles; *s. sp.*, short spicule. × 80. (Original.)

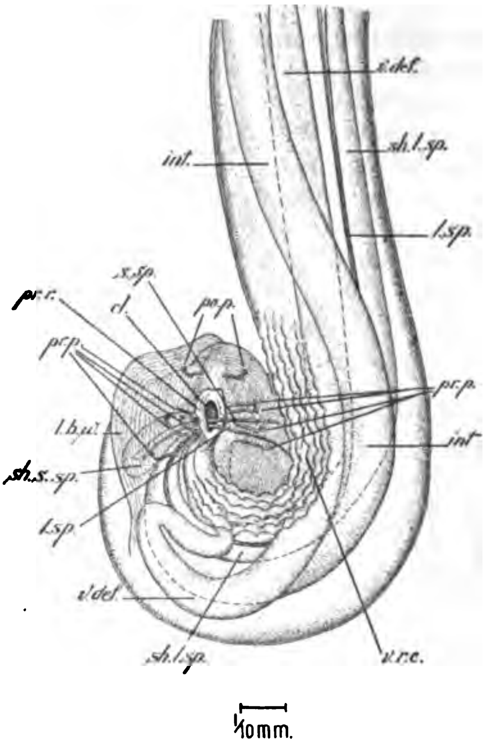

FIG. 8.—*Arduenna strongylina.* Posterior end of body of male, viewed from left side. *cl.*, cloaca; *int.*, intestine; *l. b. w.*, left bursal wing; *po. p.*, postanal papillæ; *pr. p.*, preanal papillæ; *pr. r.*, perianal ring; *sh. l. sp.*, sheath of long spicule; *sh. s. sp.*, sheath of short spicule; *s. sp.*, short spicule; *v. def.*, vas deferens; *v. r. c.*, ventral ridge of the cuticle, × 58. (Original.)

In a cross section of *Arduenna strongylina* (fig. 9 of the present article), Ciurea (1911) shows that the interior of the lateral wing is filled with a substance shaped like the letter V when viewed in this position. In its reaction to hematoxylin it resembles the thickened wall of the pharynx.

The same drawing (fig. 9) also shows that the vagina first passes between the cuticle and muscular wall as it crosses the body to extend along the right side. In several of the specimens examined by him, Ciurea (1911) noticed a drop of hardened cement at the opening of the vulva, and in cross section it was seen that the same material filled the terminus of the vagina. This material was not seen in any of the specimens examined by the present writer.[1]

The vagina (fig. 5) extends first transversely under the uteri and intestine; then leading above these organs it continues posteriorly and parallel with the intestine (except for an S-shaped bend near its middle) along the right side until it reaches the junction of the uteri.

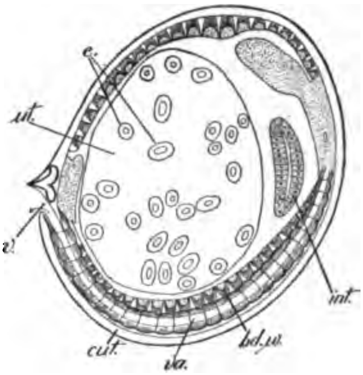

FIG. 9.—*Arduenna strongylina.* Cross section through body of female in the region of the vulva. *bd. w.*, body wall; *cut.*, cuticle; *e.*, eggs; *int.*, intestine; *ut.*, uterus; *v.*, vulva; *va.*, vagina. Enlarged. (After Ciurea, 1911. Text fig. 1, p. 131.)

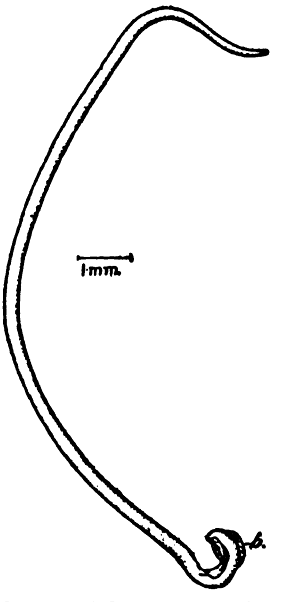

FIG. 10.—*Arduenna strongylina.* General view of body of male from right side. *b.*, bursa. × 7. (Original.)

One of the uteri, commencing at the end of the vagina, extends posteriorly and dorsally without convolutions (except for an S-shaped bend 875 μ from its vaginal end) until it reaches a point 3.6 mm. from its union with the vagina. Here it makes an abrupt turn, runs back anteriorly and ventrally, parallel with its dorsal limb, until its outline is lost to view beneath the mass of eggs distending both uteri and filling the body cavity from the end of the esophagus to within a short distance of the anus, greatly obscuring the outlines of the organs. Throughout its visible length this uterus is of nearly uniform diameter, about 95 μ. The distal ends of the two uteri are at opposite extremities of the worm; the uterus that first extends posteriorly ends anteriorly at a point 613 μ anterior of the base of the esophagus in a long convoluted ovary crowded into the narrow space between the esophagus and the lateral muscular wall. The other uterus, running in a similar but reverse direction from the uterus just described, turns first anteriorly for about 3.5 mm., then posteriorly, ending at a point about 875 μ from the tip of the tail. The diameter of the posterior uterus, like that of the anterior uterus, is nearly uniform, about 95 μ. The posterior ovary, much convoluted, fills most of the space between the anus and the terminus of the posterior uterus (fig. 4). The ovaries are long filiform tubes, 34 μ in diameter in their narrowest part. The thick-shelled eggs are covered with a thin irregular membrane resembling the albuminous membrane of an ascarid egg. Under high power a faint line at either pole can be seen running transversely through the thickness of the shell, suggesting an operculum. The embryo is surrounded by a thin envelope, differentiated from the shell by its greater translucence and lack of granulation (fig. 6). Most of the eggs in the uterus contain well-developed embryos, but a few near the ovaries appear in the morula stage. The shell, including the translucent membrane surrounding the embryo, is 4 μ thick, the embryo occupying a space 11 μ by 24 μ.

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[1] Such a secretion is not, however, uncommon among nematodes. The writer has collected many specimens of *Œsophagostomum columbianum* the vulva of which was closed by a plug of dark-red secretion insoluble in alcohol but which could easily be removed by a needle. Specimens of this parasite have been observed so firmly welded in copulation that hot alcohol did not cause their separation and they yielded only to forcible traction with a needle or forceps.

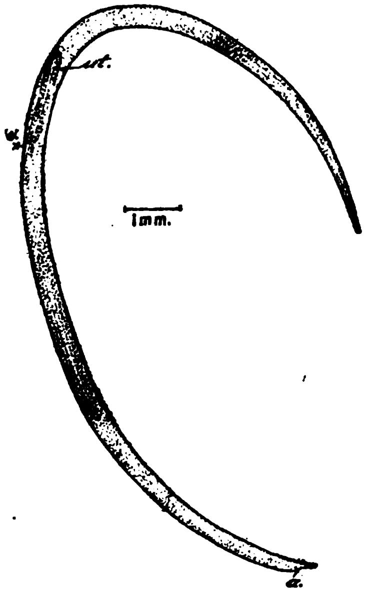

FIG. 11.—*Arduenna strongylina*. General view of body of female from left side. a., anus; ut., uterus; v., location of vulva. × 7.5. (Original.)

The general appearance of the two sexes is represented in figures 10 and 11.

The first specimens of *Arduenna strongylina* were collected by Bremser and figured by him in his Icones Helminthum (Bremser 1824c). They were first described, however, by Rudolphi (1819a, p. 237). His description may be freely translated as follows:

> Head slender, continuous, mouth orbicular, body somewhat attenuated anteriorly, tail of male coiled either in a single spiral or in a spiral and a half. A broad wing extending on either side of the tail. Spicule very long. Apex of the tail very short, naked. Apex of the tail of the female depressed, straight, subacute.

In a preliminary note Rudolphi (1819a) gives the measurement of the males as about 5 lines long (=10.6 mm.) and the females as 7 lines long (=14.9 mm.).

Gurlt (1831a) is the first on record to collect the worm from domestic swine. His description of the anatomy of *Spiroptera strongylina* follows Rudolphi's, but contains also the statement that the vulva is situated a short distance in front of the anus. He describes the mouth as smooth, without papillæ. Subsequently (Gurlt, 1847a) he added to his description a note on the anatomy of the pharynx, the first reference to this structure, which he describes as banded by two spiral muscles (a misinterpretation of the spiral chitinous ridges of the pharynx) running the length of the esophagus in opposite directions (fig. 12).

Molin (1860b) describes the vulva as situated posteriorly, and gives the following measurements: Males, 11 to 15 mm; females, 15 to 23 mm, which figures agree closely with the writer's measurements of *Arduenna strongylina.*

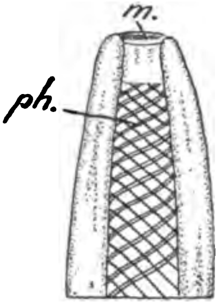

FIG. 12.—*Arduenna strongylina.* Cephalic end. *m.*, mouth; *ph.*, pharynx. Enlarged. (After Gurlt, 1847a, Pl. I, fig. 8.)

Schneider (1866a) reexamining Rudolphi's material, gives a correct drawing of the bursa of *Arduenna strongylina,* showing 5 pairs of papillæ, of which one pair is postanal, and describes the anus as surrounded posteriorly by a crown of serrated cuticular prominences (fig. 13). His description, however, does not in all respects agree with his drawing, as he states that there are 6 pairs of papillæ while the drawing shows only 5 pairs. His description is also in error in regard to the position of the vulva, which he describes as directly in front of the anus.

Von Linstow (1879b) states that the two spicules measure respectively 0.72 and 0.26 mm. and that the mouth is surrounded with 6 round papillæ curved forward (fig. 14). His drawing shows the pharynx with a series of parallel ridges instead of a spiral. A comparison of his drawing (fig. 14) with the anterior end of *Physocephalus sexalatus* (fig. 15) gives rise to the suspicion that Von Linstow has mistaken this species for *Arduenna strongylina,* an opinion first expressed by Railliet and Henry (1911b).

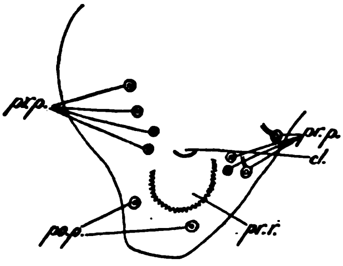

FIG. 13.—*Arduenna strongylina.* Bursa of male, ventral view. *cl.*, cloaca; *po. p.*, postanal papillæ; *pr. p.*, preanal papillæ; *pr. r.*, perianal ring. Enlarged. (After Schneider, 1866a, p. 101.)

Zuern (1882a) is the first to mention the narrow lateral wing, extending longitudinally along one side of the body. He describes it, however, as being in a median position. As has been shown, it extends along the left side only.

Stossich (1897b) states that the long spicule is three times the length of the short spicule, a ratio evidently derived from Von Linstow's (1879b) measurements.

At a meeting of the Helminthological Society of Washington, the writer (Foster, 1911) presented a note on *Spiroptera strongylina* in which he pointed out the differences between the anatomical features of specimens tentatively identified by him as *Spiroptera strongylina* and the descriptions of this species by European observers. As no European specimens were at hand with which to compare the specimens collected in this country, it was concluded either that the American form represented a distinct species or else the descriptions of European writers were in error in some important details. In order to determine which of the two alternatives was correct, specimens collected in the United States were forwarded to Prof. von Linstow for comparison with specimens collected in Europe, and other European helminthologists were asked for specimens of *Spiroptera strongylina*. The specimens sent to Von Linstow were considered by him to be a different species from *Spiroptera strongylina*. There is, however, no question that certain European specimens recently received from Prof. Gedoelst, of Brussels, are specifically identical with the American form, nor can it be doubted that the form taken by Railliet and Henry (1911b) as *Spiroptera strongylina* is the same as the American form.

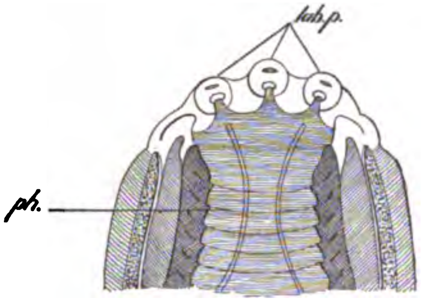

FIG. 14.—*Physocephalus sexalatus*. Lateral view of cephalic end. *lab. p.*, labial papillæ; *ph.*, pharynx. Enlarged. (After Von Linstow, 1879b, Pl. V, fig. 11.)

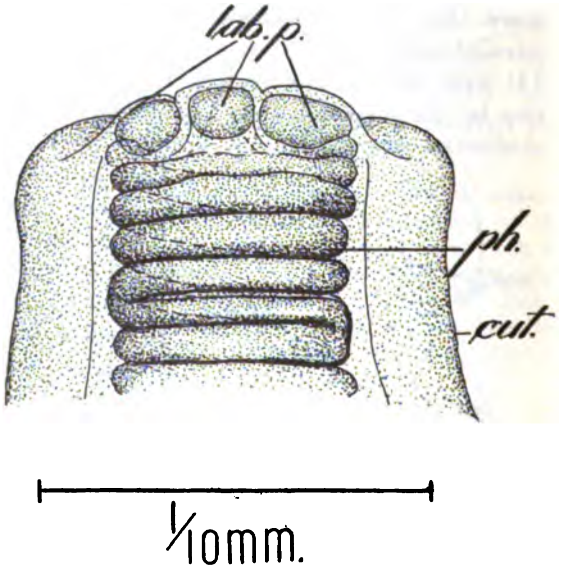

FIG. 15.—*Physocephalus sexalatus*. Lateral view of cephalic end. *cut.*, cuticle; *lab. p.*, labial papillæ; *ph.*, pharynx. × 415. (Original.)

In regard to the length of the spicules of *Arduenna strongylina*, the writer's observations are not in accord with those of Ciurea (1911). Measurements of the spicules of over 35 males made with the aid of a camera lucida and stage micrometer show that the long spicule varies between 2.24 and 2.95 mm. in length, while the short spicule is between 457 and 619 μ in length. The corresponding measurements given by Ciurea are, long spicule, 977 μ; short spicule, 221 μ. The measurements given by Railliet and Henry (1911b) are, long spicule, 2.75 to 2.9 mm.; short spicule, 500 to 570 μ, thus confirming the present writer's observations.

Arduenna strongylina, considered a rare parasite by Dujardin (1845a), Neumann (1892a), and Railliet (1893a), is now known to have a wide range. In this country at least it is very common, as will be shown later. In Europe it has been collected from the wild boar by Bremser (Rudolphi, 1819a) in Germany, and is reported by Dujardin (1845a) in Austria, and by Railliet and Henry (1911b) in France from the same host. It has been reported for domestic swine in Germany (Gurlt, 1831a), Hungary (Von Rátz, 1899d), Italy (Piana, 1897e), and Roumania (Ciurea, 1911). Most helminthologists, following the older writers, state that the parasite is rare and occurs somewhat more commonly in the wild boar than in domestic swine. Dujardin (1845a) states that "out of 19 wild boars dissected at the museum of Vienna, only 2 had this worm in the stomach." In Roumania, Ciurea found it in 9 out of 72 healthy swine, between 1 and 27 specimens being found in a single host. Outside of Europe it has been reported by Von Linstow (1886c) from Turkestan, and by Railliet and Henry (1911b) from Annam Province, Indo-China. Some doubt, however, may be expressed regarding the identity of the parasite reported by Von Linstow (1886c) since, as has been shown, Von Linstow (1879b) has apparently confused *Physocephalus sexalatus* with *Arduenna strongylina*. The references to this parasite in the United States will be considered in detail in another part of the paper. Judging from its abundance in the United States, it seems not improbable that a careful examination of hogs' stomachs in European slaughterhouses would show a more widespread infection than hitherto reported. The specimens received by this bureau from Gedoelst were unaccompanied with any data giving the host or locality. Doubtless many veterinary schools and colleges throughout Europe contain specimens both of this parasite and of *Physocephalus sexalatus* which, like the specimens received from Gedoelst, have never been reported in the literature.

An examination of the literature reveals only two authentic hosts for *Arduenna strongylina*, namely, the European wild boar and domestic swine, although most writers subsequent to Diesing (1851a) have included the peccary in their lists of hosts.

Diesing (1851a) identified as *Spiroptera strongylina* some specimens of worms in the Vienna museum collected by Natterer in Brazil, April 24, 1826, from the stomach of the white-lipped peccary (*Dicotyles labiatus*) and labeled *Spiroptera suis labiati*. As a result of his identification he (Diesing, 1851a) added *Dicotyles albirostris* (=*Dicotyles labiatus* Cuv.)[1] to the previously known hosts of *Spiroptera*

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[1] Dr. H. W. Henshaw, Chief of the Bureau of Biological Survey of the United States Department of Agriculture, in reply to a letter regarding the synonymy of *Dicotyles labiatus*, states (Feb. 24, 1911) that, according to Dr. J. A. Allen, of his bureau, *Dicotyles labiatus* and *albirostris* are synonyms, *labiatus* having preference as being the older term, the correct name, however, being *Tayassu pecari* Fischer.

strongylina. The specimens were subsequently studied by Molin (1860b), recognized as a new species, and named by him *Spiroptera sexalata.* Later helminthologists, although accepting Molin's species, have continued to include *Dicotyles labiatus* among the hosts reported for *Arduenna strongylina,* apparently ignoring the fact that Molin's (1860b) correction of Diesing's (1851a) identification eliminates the peccary as a host of *Arduenna strongylina,* since this species has never been reported in the peccary except by Diesing (1851a). Stossich (1897b) apparently considered *Dicotyles albirostris* and *D. labiatus* as separate species, listing under the former *Spiroptera strongylina* and under the latter the parasites collected by Natterer from the peccary and described by Molin (1860b).

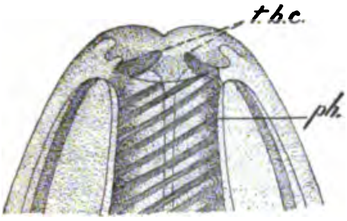

FIG. 16.—*Arduenna dentata.* Median view of cephalic end. *ph.*, pharynx; *t. b. c.*, teeth of the buccal capsule. Enlarged. (After Von Linstow, 1904f, Pl. I, fig. 5.)

The stomach appears to be the normal location for *Arduenna strongylina;* Von Râtz (1899d), however, reports its occurrence in the small intestine.

Arduenna dentata (Von Linstow, 1904) Railliet and Henry, 1911.

Von Linstow's (1904f) description of this species is as follows:

> Cuticula finely annulated. The mouth leads into a pharynx 0.11 mm. long. Its entrance is armed with a dorsal and a ventral tooth; the mouth is a transverse slit, the border of which shows both anteriorly and posteriorly, three notches with papillæ (fig. 16). The esophagus measures $\frac{1}{8.6}$ of the entire length and presents a spiral musculature. In a young worm 14.6 mm. long, the nerve ring surrounds the esophagus 2.64 mm. from the head end, and the excretory pore opens at a point situated 0.31 mm. behind it. The male (25 mm. long by 0.79 mm. broad) has a closely involuted tail which resembles that of *Spiroptera strongylina.* The spicules are respectively 0.35 and 0.92 mm. long, the shorter one bearing at its end a barb. Immediately anterior of the anus on each side there are four preanal papillæ situated close together; behind it there is one papilla. All have long stalks. The anus is surrounded by a broad ring, notched externally; the bursa shows longitudinal rows of oval scales. (Fig. 17). The female grows to a length of 55 mm. with a width of 1.10 mm. The short conical tail is curved over the back; the vulva is placed far behind the middle and divides the body in the ratio of 70 to 23. The eggs are small, thick shelled, and cylindrical, measuring 0.039 by 0.017 mm.

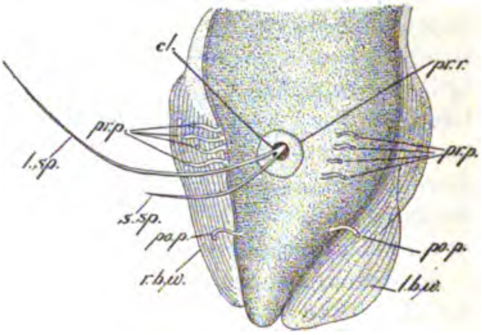

FIG. 17.—*Arduenna dentata.* Bursa of male, ventral view. *cl.*, cloaca; *l. b. w.*, left bursal wing; *l. sp.*, long spicule; *po. p.*, postanal papillæ; *pr. p.*, preanal papillæ; *pr. r.*, perianal ring. Enlarged. (After Von Linstow, 1904f, Pl. I, fig. 7.)

The specimens described by Von Linstow were from the stomach of *Sus cristatus* at Chilaw, Ceylon, and are deposited in the museum of Colombo. Railliet and Henry (1911b) identify with Von Linstow's (1904f) *Spiroptera dentata* certain parasites collected from the stomachs of pigs slaughtered at Hué, Annam Province, Indo-China, and include them in the genus *Arduenna.* The specimens examined by Railliet and Henry (1911b) differ, however, from Von Linstow's (1904f) description in the position of the vulva and the length of the spicules. According to the former authorities, the position of the vulva is difficult to observe, but the spicules measure 3.75 to 4.23 mm., and 540 to 650 μ, respectively.

The principal differences between *Arduenna dentata* and *Arduenna strongylina* are the greater size of the former and the fact that the chitinous ring surrounding the cloacal opening, described for *Arduenna strongylina,* forms an almost complete circle in the case of *Arduenna dentata,* while in *Arduenna strongylina* it includes only the posterior and left sides. Railliet and Henry's measurements for *Arduenna dentata* are: Males: 25 to 35 mm. long by 700 to 800 μ broad; females: 40 to 55 mm. long by 1.1 to 1.2 mm. broad.

Genus PHYSOCEPHALUS Diesing, 1861.

GENERIC DIAGNOSIS.—Filariidæ: Body elongated, subcylindrical, slightly tapering anteriorly. Head marked off from the rest of the body by a cuticular inflation ending abruptly in a circular line a short distance anterior of the posterior end of the pharynx. Extending from the base of the cuticular inflation to about the middle of the body are 6 lateral cuticular wings, 3 on each side, the middle wing of each 3 being broader than the other two. Mouth with 2 trilobed lips, with a rounded papilla on each lobe, and leading into an inconspicuous buccal capsule without teeth. Pharynx relatively long and broad, marked by prominent ridges forming both spirals and simple rings, and extending the length of the pharynx on the inside. Tail of the male twisted spirally, furnished with a narrow symmetrical bursa supported by four pairs of preanal papillæ. Spicules long and unequal, the left spicule about five times the length of the right spicule. Vulva somewhat posterior of the middle of the body; eggs smooth, with thick shells, containing well-developed embryos at the moment of oviposition. Endoparasitic in the stomach of suidæ.

TYPE SPECIES.—*Physocephalus sexalatus* (Molin, 1860) Diesing, 1861.

Physocephalus sexalatus (Molin, 1860) Diesing, 1861.

1860: *Spiroptera sexalata* Molin, 1860b, p. 957.

1860: *Spiroptera strongylina suis labiati:* Molin, 1860b, p. 957 (Museum label).

1861: *Physocephalus sexalatus* (Molin) Diesing, 1861a, p. 686.

SPECIFIC DIAGNOSIS.—*Physocephalus:* Head about 60 μ in diameter at the anterior end, furnished with 2 trilobed lips, each lobe being ornamented with a thick, rounded chitinous papilla (fig. 15). The cuticle of the head, extending from the mouth to a point 232 μ from the anterior end, is more or less inflated. Pharynx cylindrical, 263 to 315 μ long by 53 μ wide, furnished with a spiral band which usually breaks up into separate rings in the middle of its course and resumes the spiral toward the posterior end. The number of turns to the spiral varies between 21 and 25. There is a cervical papilla on the left side, 281 μ from the anterior end. The excretory pore opens on the right side, 526 μ from the anterior end. The lateral cuticular wings, 3 on each side, commencing at the base of the cephalic cuticular inflation, extend posteriorly for a distance about one-third of the body length. The middle wing of each three is 60 μ wide at its middle, the point of greatest width. The other wings are about half as wide (fig. 18).

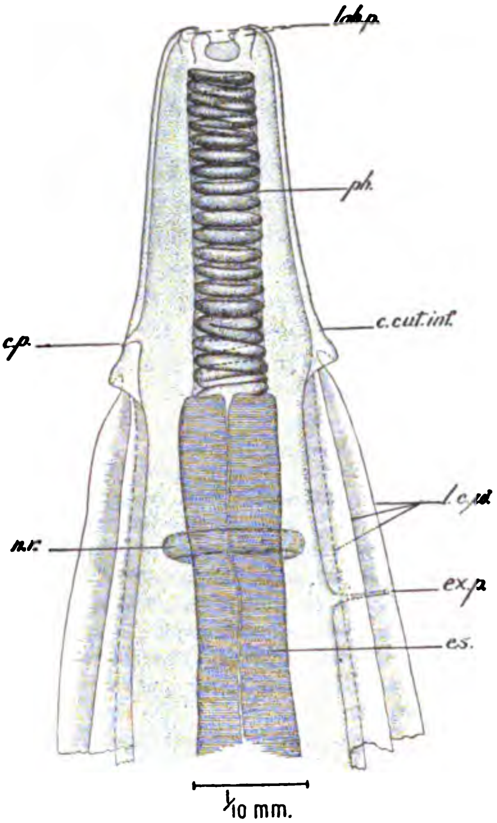

FIG. 18.—*Physocephalus sexalatus.* Dorsal view of anterior end of body. *c. cut. inf.*, cephalic cuticular inflation; *c. p.*, cervical papilla; *es.*, esophagus; *ex. p.*, excretory pore; *lab. p.*, labial papillæ; *l. c. w.*, lateral cuticular wings; *n. r.*, nerve ring; *ph.*, pharynx. × 150. (Original.)

Male, 6 to 9 mm. long, measured in a straight line. Body nearly uniform in diameter, averaging 263 μ, and attaining its greatest width of 315 μ at the point of the greatest width of the lateral wings. The narrow bursal membranes, about half the width of the body, extend from a point about 1.4 or 1.5 mm. from the caudal extremity, to and including the bluntly pointed tip (fig. 19). Caudal extremity twisted into a fairly regular spiral, having usually three turns. Long spicule grooved on the ventral side, 2.1 to 2.25 mm. in length, or five to six times the length of the short spicule, very slender, gradually tapering to a fine needle point. Short spicule 300 to 350 μ long, relatively broad at its base, suddenly tapering to a fine point. The ventral surface of the short spicule is provided with a narrow wing extending nearly to the tip. Bursa furnished with eight pairs of papillæ (fig. 20). Of these the four pairs of preanal papillæ are long and stalked; the postanal papillæ, close to the tip of the tail, are very small, with short stalks.

Female 13 to 19 mm. long, average about 16 or 17 mm. Maximum width 333 to 450 μ in the region directly anterior of the anus. The body rapidly increases in diameter from the anterior end to the region of greatest width of the lateral cuticular wings. At this point the diameter is nearly as great as in the region of the anus. It then rapidly diminishes to half as much at the end of the first third of the body; then slowly increasing, it reaches a maximum near the anus and abruptly diminishes, the body ending in a blunt point furnished with a mucronate tip. Anus 120 μ from the caudal end, 50 μ in diameter (fig. 21). Vulva posterior of the middle, 35 μ in diameter, dividing the body in the ratio of 9 to 8. The vagina extends posteriorly (fig. 22). Uterus bilobed, the ovaries lying at opposite extremities. Eggs 34 by 15 μ, slightly flattened at the poles. Embryo well developed before oviposition (fig. 23).

HOSTS.—White-lipped peccary (*Tayassu pecari*), wild boar (*Sus scrofa fera*), domestic hog (*Sus scrofa domestica*).

LOCATION.—Stomach and small intestine.

LOCALITIES COLLECTED.—Brazil; Italy; Germany; Roumania; Madagascar; Indo-China; United States, east, middle, and southwest. (Apparently same range as *Arduenna strongylina*.)

As already mentioned, *Physocephalus sexalatus* was first identified as *Spiroptera strongylina* by Diesing (1851a). Molin (1860b) subsequently described the specimens under the name *Spiroptera sexalata*, and the following year Diesing (1861a) placed the species in a new genus *Physocephalus*, of which it is the type and only species. The specimens studied both by Molin and Diesing were collected by Natterer from the white-lipped peccary in Brazil, April 24, 1826, and deposited in the Vienna Museum labeled *Spiroptera strongylina suis labiati*.

Molin's (1860b) somewhat meager description sums up the salient points (the lateral wings and spiral tail of the male) by which *Physocephalus sexalatus* may be recognized. He describes the males as 7 mm. long and 2 mm. wide, and the females as 9 to 13 mm. long and 3 to 5 mm. wide. The mouth is described as bilobed, each lobe with a three-cornered margin. Diesing (1861a), although creating a new genus from Molin's species, adds little to our knowledge of its anatomy.

It has already been noted that Von Linstow (1879b) has apparently mistaken *Physocephalus sexalatus* for *Arduenna strongylina*. His measurements of the spicules (0.72 mm. for the long and 0.26 mm. for the short spicule) are, however, much too short for *A. strongylina* and also for *P. sexalatus*.

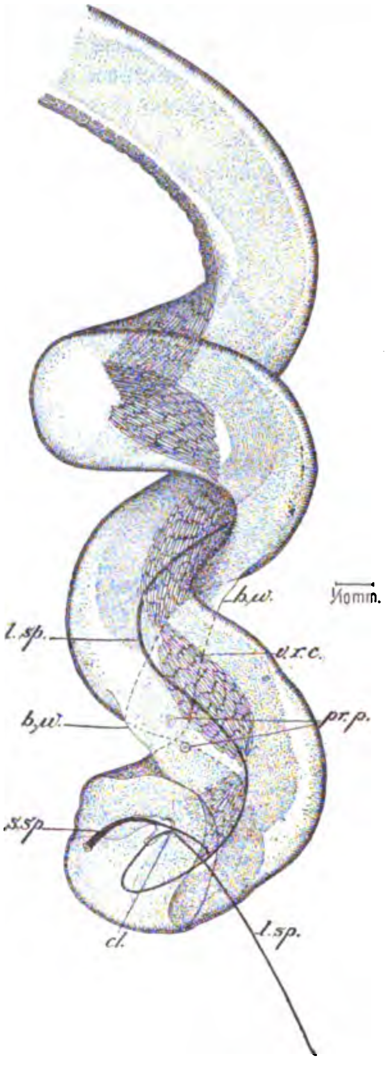

FIG. 19.—*Physocephalus sexalatus*. Posterior end of body of male. *b. w.*, bursal wing; *cl.*, cloaca; *l. sp.*, long spicule; *pr. p.*, preanal papillæ; *s. sp.*, short spicule; *v. r. c.*, ventral ridge of the cuticle. × 50. (Original.)

Von Drasche (1884a), in his reexamination of Diesing's and Molin's specimens, made a careful study of the bursal papillæ and the structure of the lateral wings, illustrating the description with drawings, which were of great value to the present writer in verifying his identification. In common with Railliet and Henry (1911b) the present writer was unable to find the pair of papillæ depicted by Von Drasche (1884a, fig. 24 of this article) close to the edge of the anus. Ciurea (1912), however, depicts a pair of papillæ immediately posterior of the anus, which he states are not easily seen. At the extreme tip of the tail Von Drasche (fig. 24) shows three pairs of minute apparently sessile papillæ. In reality there are four pairs of minute stalked papillæ at this point. These appeared very clearly with a high power in mounts presenting a somewhat lateral view (fig. 20). The structure at the tip of the tail with its rows of minute papillæ is not unlike that depicted by Ciurea (1911) for the bursa of *Arduenna strongylina*. As already stated, however, no such structure was seen by the present writer on the bursa of this species. In a cross section of *P. sexalatus* (fig. 25) Von Drasche shows that the projecting cuticle forming the lateral wings has corresponding depressions inward.

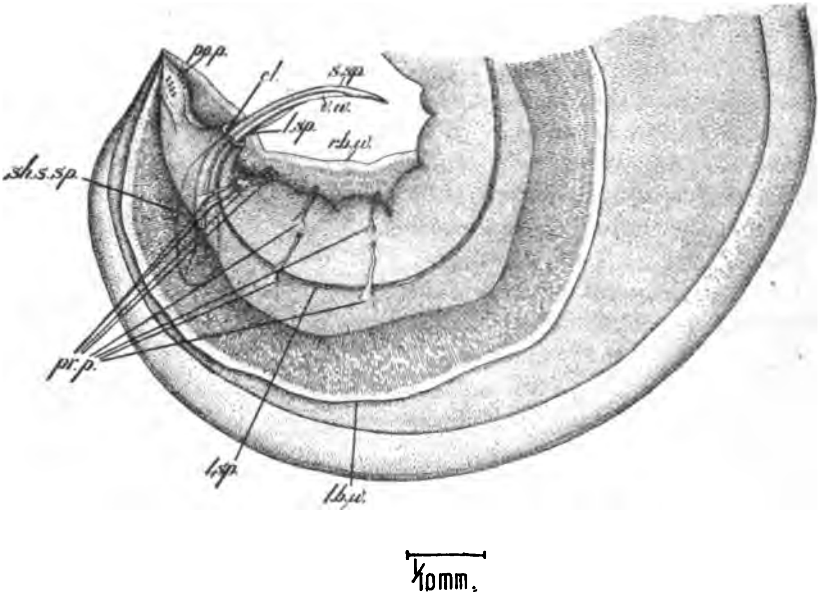

FIG. 20.—*Physocephalus sexalatus.* Bursa of male, viewed from left side. *cl.*, cloaca; *l. b. w.*, left bursal wing; *l. sp.*, long spicule; *po. p.*, postanal papillæ; *pr. p.*, preanal papillæ; *r. b. w.*, right bursal wing; *sh. s. sp.*, sheath of short spicule; *s. sp.*, short spicule; *v. w.*, ventral wing of short spicule. × 100. (Original.)

Stossich's (1897b) description of *P. sexalatus* follows that of Molin and Von Drasche. Piana (1897e), in an article on *Simondsia paradoxa*, mentions finding two other species of nematodes in the same bottle containing the specimens of *Simondsia.* He identified these as being *Spiroptera strongylina* and *Physocephalus sexalatus.* These specimens were from an Italian pig.

Railliet and Henry's (1911b) description of *Physocephalus sexalatus* is based on specimens collected from a hog slaughtered at Hué, Indo-China. These authors also report having observed it in material from Madagascar in 1905.

Ciurea (1912) reported *Spiroptera sexalata* in domestic swine slaughtered at Piatra Neamtz, Roumania, in 1910. Five out of 72 healthy swine were infested with from one to thirty of these parasites in the stomach. In three cases they were found associated with *Arduenna strongylina*, and once with *Gnathostoma hispidum*. In this latter case the parasites were found in the ulcer caused by *G. hispidum*. The worms were partially or entirely buried in the mucosa, but no lesions were attributed to them. Ciurea's (1912) description and drawings of *Physocephalus sexalatus* agree in most respects with the present writer's observations, the few differences being noted in the course of this article.

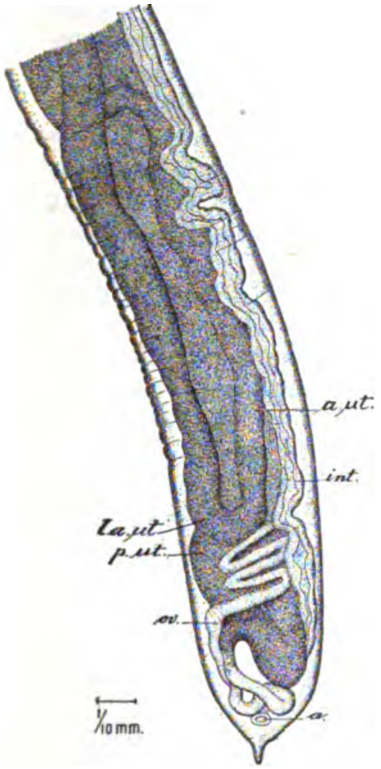

FIG. 21.—*Physocephalus sexalatus*. Posterior end of body of female, ventral view. *a.*, anus; *a. ut.*, anterior uterus; *int.*, intestine; *l. a. ut.*, loop of anterior uterus; *ov.*, ovary; *p. ut.*, posterior uterus. × 50. (Original.)

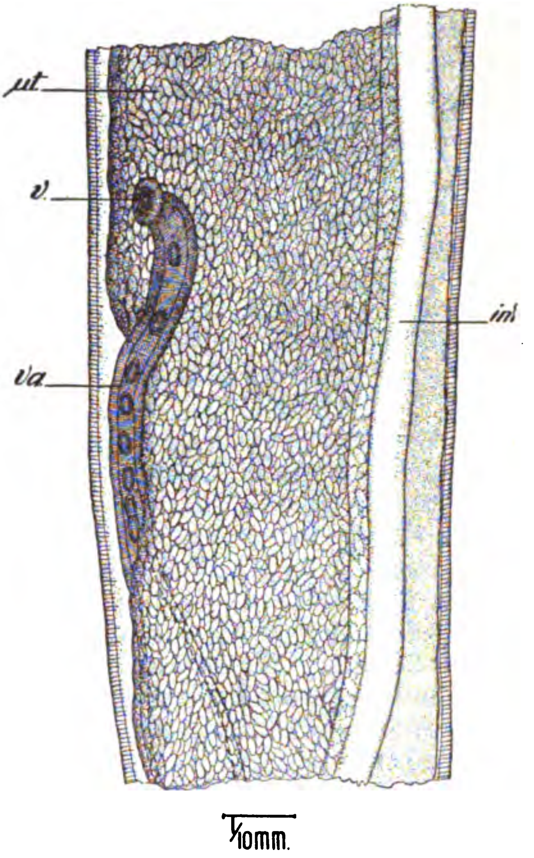

FIG. 22.—*Physocephalus sexalatus*. Ventral view of body of female in the region of the vulva. *int.*, intestine; *ut.*, uterus; *v.*, vulva; *va.*, vagina. × 95. (Original.)

Seurat (1912) reports finding several hundred specimens of *Spiroptera sexalata* partially buried in the mucosa of the stomach of an ass slaughtered in Algeria during July, 1911. A subsequent examination of the fourth stomachs of six dromedaries revealed numerous specimens of this species hidden between the folds of the mucosa, associated with *Hæmonchus contortus*. While the description of the specimens agrees in general with the present writer's observations, the measurements are all somewhat larger. The width of the middle lateral wing (110 to 120 μ as given by Seurat) is over twice as great as that given by the present writer, while the vulva is described as located at the anterior third of the body, instead of slightly posterior of the middle, as described by Railliet and Henry (1911b), Ciurea (1912), and Foster (1912) (the present article).

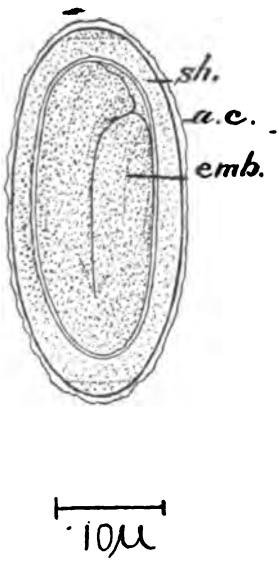

FIG. 23.—*Physocephalus sexalatus*. Lateral view of egg removed from a ruptured uterus. *a. c.*, albuminous covering; *emb.*, embryo; *sh.*, shell. × 1,450. (Original.)

Seurat (1912) also found in the dromedary another form which he considers as a variety and designates as var. *cristata*. This form is distinguished from the typical species by having four longitudinal crests on the head, formed by four cuticular folds, and having four cuticular spines in the mouth cavity. In this variety the position of the vulva is not constant, but varies from the posterior third of the body to an anterior position.

As Seurat's (1912) measurements of *Physocephalus sexalatus* differ considerably from the present writer's, and as the species has hitherto been reported only in the Suidæ, it would seem desirable to reserve an opinion until his statements can be confirmed.

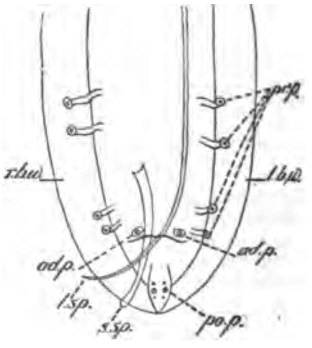

FIG. 24.—*Physocephalus sexalatus*. Bursa of male, ventral view. *ad. p.*, adanal papillæ; *l. b. w.*, left bursal wing; *l. sp.*, long spicule; *po. p.*, postanal papillæ; *pr. p.*, preanal papillæ; *r. b. w.*, right bursal wing; *s. sp.*, short spicule. × 280. (After Von Drasche, 1884a, Pl. XIV, fig. 3.)

The stomach is the normal location for *Physocephalus sexalatus*. Von Linstow (1879b) reports *Filaria strongylina* as collected from the small intestine of a hog by Dr. V. Hering, of Stuttgart. As has been shown, Von Linstow apparently confused *Physocephalus sexalatus* with *Arduenna strongylina*; it would seem therefore, that *P. sexalatus* may occasionally occur in the small intestine.

In most specimens examined by the author the cuticle of the head appears as shown in fig. 18, which is closely similar to the form depicted by Von Drasche (1884a). In about 20 per cent of the specimens examined, however, the cuticle, from the lips to the beginning of the lateral cuticular wings, is inflated into two hemispherical vesicular wings (fig. 26). This second form is not mentioned by Molin (1860b) or Von Drasche (1884a), but possibly may be referred to by Diesing (1861a) in the expression "epidermide in bullam inflata tunicatum" in his description of the genus *Physocephalus*.

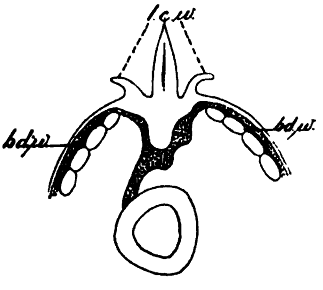

FIG. 25.—*Physocephalus sexalatus*. Cross section through anterior part of body. *bd. w.*, body wall; *l. c. w.*, lateral cuticular wings. × 280. (After Von Drasche, 1884a, Pl. XIV, fig. 4.)

The pharynx of *P. sexalatus* is about three times as long and twice as broad as that of *Arduenna strongylina*, and this, together with the lateral wings characteristic of the genus, are the salient points in distinguishing the females of the two genera. At first sight the ridges of the pharynx appear to form separate rings and are so described by Von Linstow (1879b and *in litt*). By careful focusing, however, it is seen that these ridges form a simple spiral at the anterior end of the pharynx and after making four or five turns split up into separate rings. At the posterior end of the pharynx they are again joined into a simple spiral (fig. 18). The final loop of the anterior spiral forms the first ring of the series, and the beginning of the posterior spiral takes its origin from the lower part of the last ring. The number of loops to the spirals and the number of separate rings is subject to considerable variation. A rather extreme case is seen in fig. 27. Here the first spiral has five loops followed by a detached ring. This in turn is followed by a spiral of four loops, after which are two detached rings. The final spiral consists of 11 continuous loops. In every case, however, so far as observed, the ridges form both spirals and rings, commencing and ending with a spiral, and

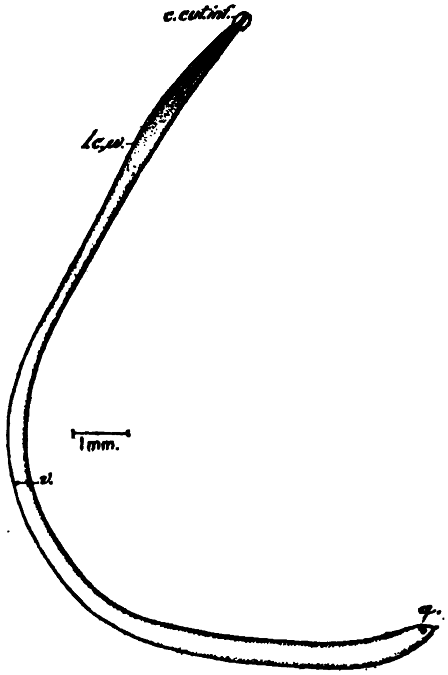

FIG. 26.—*Physocephalus sexalatus*. Ventral view of body of female. *a.*, anus; *c. cut. inf.*, cervical cuticular inflation; *l. c. w.*, lateral cuticular wings; *v.*, vulva. × 7. (Original.)

not a series of parallel bands, as described by Von Linstow (1879b), or a continuous spiral, as described by Von Drasche (1884a), Railliet and Henry (1911b), and Ciurea (1912).

Raillie t and Henry (1911b) mention two asymmetrical cervical papillæ, the right papilla being 220 μ and the left 420 μ from the anterior end. As seen by the present writer the left papilla has a broad base and a blunt point and penetrates the cuticle 281 μ from the anterior end, or a little anterior of the base of the cephalic inflation. The right papilla was not seen by the present writer, but on the right side, not far from the location of the papilla as given by Railliet and Henry (1911b), the excretory canal opens. The end of the canal is a slender tube penetrating the middle lateral wing and looking not unlike a long stalked papilla (fig. 18). Its true nature has been shown by Ciurea (1912), who made a cross section of the worm at this point. The lateral situation of the excretory pore is apparently unique among nematodes, the usual situation being ventral.

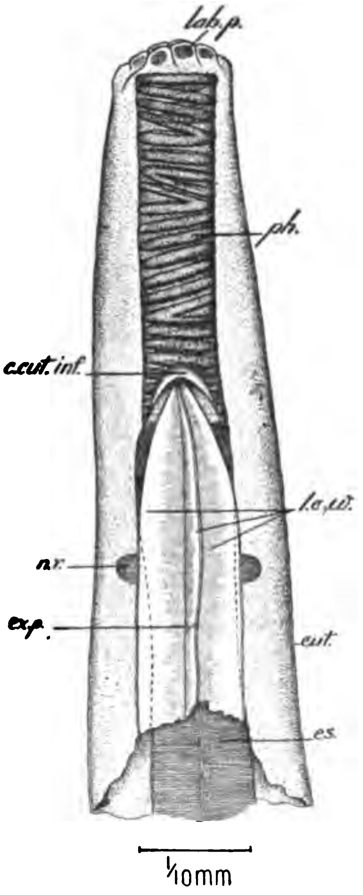

FIG. 27.—*Physocephalus sexalatus.* Lateral view of anterior end of body. *c. cut. inf.*, cervical cuticular inflation; *cut.*, cuticle; *es.*, esophagus; *ex. p.*, excretory pore; *lab. p.*, labial papillæ; *l. c. w.*, lateral cuticular wings; *n. r.*, nerve ring; *ph.*, pharynx. × 150. (Original.)

The lateral cuticular wings unite just posterior of the base of the cephalic inflation (fig. 18). Here the cuticle forms an inverted pocket like the handle of a table drawer (fig. 27). The lateral cuticular wings are densely striated at the base, giving them a puckered appearance. Although the cuticle of the entire body is striated, these striations appear more prominently on the lateral wings, particularly at their base, than elsewhere. The esophagus, about four-fifths of the length of the lateral wings, is densely striated transversely, with a very narrow lumen; nerve ring 439 μ from the anterior end (fig. 18). The intestine is more or less convoluted throughout its course, especially posteriorly.

The male (fig. 28) is about half the length of the female, but as 2 to 3 mm. of the posterior end is twisted into a spiral, its apparent length is much shortened.

The spiral of the caudal end of the male appeared in a few cases as a single coil like that of *Arduenna strongylina.* In other cases it consisted of an irregular double twist (fig. 28). .In the greater number of specimens examined, however, it formed a broad open spiral like a corkscrew (fig. 19). Comparing the spiral to the thread of a screw, and considering the tip of the tail as the point of the screw, the spiral resembles a left-handed screw with three (rarely four) threads; no cases were seen in which the spiral revolved in the opposite direction.

The bursal wings are described as symmetrical by Railliet and Henry (1911b) and are so depicted by Von Drasche (1884a). The right wing is, however, a little longer than the left wing (fig. 19). Ciurea (1912) considers that it is also narrower, but this statement could not be verified by the present writer. Ciurea (1912) states that the bursal wings extend throughout the twisted portion of the tail. As seen by the present writer they extend only about half this distance (fig. 19). The cuticle on the ventral side of the male (fig. 19), commencing at some distance anterior of the spiral, is marked with longitudinal striations intercepted by transverse lines, appearing under high power as longitudinal folds of the cuticle separated by transverse ridges. A similar structure has already been noted on the ventral surface of *Arduenna strongylina* (fig. 2). As in most nematodes, the papillæ are arranged symmetrically on either side of the median line. Their grouping and structure have already been discussed.

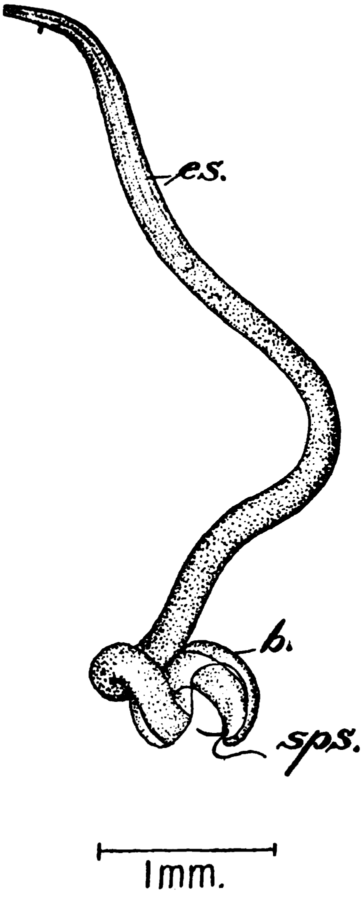

FIG. 28.—*Physocephalus sexalatus.* General view of body of male. *b.*, bursa; *es.*, esophagus; *sps.*, spicules. × 23. (Original.)

The intestine is much convoluted, growing broader close to the cloaca. The vesicula seminalis occupies most of the body cavity in the posterior end, maintaining a fairly uniform diameter until it disappears dorsal of the intestine which conceals the ductus ejaculatorius. The long convoluted testis which extends to the middle of the body presents no specific characteristic features. The anus is circular, like that of *Arduenna strongylina*, but not surrounded by a serrated ring.

The vulva (35 μ in diameter), as in *Arduenna strongylina*, apparently occupies a somewhat lateral rather than ventral position, opening toward the right side (fig. 22). It is situated just below the middle of the body, dividing the worm in the ratio of 9 to 8. According to Ciurea (1912) the cuticle in the region of the vulva is marked with longitudinal thickenings which may interlock with the cuticular ridges on the ventral surface of the male, and thus assist in maintaining the position of the male in copulation. The vagina, extending posteriorly along the right side, is at first 50 μ in diameter, but gradually broadens to 105 μ at its posterior end, where it disappears from the ventral side, extending dorsal of a lobe of the uterus. The distance from the vulva to this point is 976 μ. The wall of the vagina is relatively thick, composed of transverse muscle fibers. The lumen is 20 μ in diameter. Eggs containing well-developed embryos ready to pass out could be seen in single file in the lumen of the vagina near the opening (fig. 22). Railliet and Henry (1911b) describe the vulva as opening posteriorly at the limit of the third and four fifths of the body. Von Linstow (*in litt*) places it somewhat posterior of the middle of the body, dividing the worm in the ratio of 10 to 9.

The arrangement of the uteri and ovaries in the body of the female is, so far as could be seen, similar to that of *Arduenna strongylina*. The convoluted ovary of the posterior uterus occupies the caudal extremity of the worm, its terminus disappearing dorsal of the posterior uterus. A loop of the anterior uterus extends nearly to the caudal end. The exact length of the vagina was not determined. A loop of the posterior uterus, corresponding to the loop of the anterior uterus, lies underneath the anterior uterus and extends nearly to its terminus. The union of the vagina with the uteri was not seen, nor was the anterior ovary traced throughout its length. While neither uterus was followed throughout its entire length, the two termini, one posterior the other anterior, the posterior uterine loop, and the anterior loop, are all similar to the arrangement seen more clearly in *Arduenna strongylina*.

Ciurea (1912) depicts a pluglike protuberance at one of the poles of the eggs of *Physocephalus sexalatus*, which bears a superficial resemblance to the operculum of a Trichuris egg, but does not penetrate the eggshell as in the latter case. This feature was not seen by the present writer; however, a faint transverse line could be seen at either pole (fig. 23), which apparently is the line of fissure along which the shell breaks when the embryo is liberated.

COMPARISON OF PHYSOCEPHALUS SEXALATUS AND ARDUENNA STRONGYLINA.

The following comparison of appearances of *Arduenna strongylina* and *Physocephalus sexalatus* will assist in separating the two species without the aid of a magnifier.

Males.—Tail of *Physocephalus sexalatus* ending in a spiral, *Arduenna strongylina* ending in a single coil; *Physocephalus sexalatus* shorter and slenderer than *Arduenna strongylina.*

Females.—*Physocephalus sexalatus* straight, or nearly so; specimens preserved in alcohol when lifted out of a petri dish with a needle bend sharply in the middle. Body slenderer than *Arduenna strongylina,* except toward the posterior end, which is thicker and blunter.

Alcohol specimens of *Arduenna strongylina* are usually curved in a half circle. They are thicker in the middle of the body than *Physocephalus sexalatus* and pointed at both ends. On being lifted with a needle they do not collapse like *Physocephalus sexalatus,* but maintain their crescentic shape.

As has already been stated, Molin (1860b) was the first to distinguish this species from *Arduenna strongylina,* with which it had been confused by Diesing (1851a). Besides the specimens from the white-lipped peccary, Molin (1860b) also found two females of this species in a bottle containing specimens of *Arduenna strongylina* collected by Bremser from the stomach of the wild boar and deposited in the Vienna Museum. That it has only twice been reported in Europe in association with *Arduenna strongylina* is perhaps due to confusion of the two species, an error which appears to have occurred in at least one case (Von Linstow, 1879b). In the United States it has been found in nearly every case in which specimens of *Arduenna strongylina* have been collected.

OTHER SPECIES REFERRED TO PHYSOCEPHALUS SEXALATUS.

Two other worms have been thought by different writers to be possibly identical with *Physocephalus sexalatus,* viz, *Simondsia paradoxa* (Cobbold, 1864b) from *Sus scrofa domestica* and *Filaria nitidulans* (Schneider, 1866a) from *Tapirus americanus.*

Simondsia paradoxa was collected from the stomach of a German hog kept at Regent's Park, London, and was described by Cobbold (1864b). In a later work (1879b) Cobbold suggests the possibility of the worm being identical with *Physocephalus sexalatus.* The immensely hypertrophied uterus of *Simondsia paradoxa,* forming a rosette entirely covering the caudal end of the female, however, clearly differentiates this species from *Physocephalus sexalatus.*

In his description of *Physocephalus*, Von Drasche (1884a) suggests the possibility that Schneider's (1866a) *Filaria nitidulans* may be identical with *P. sexalatus*. Both worms are characterized by three lateral wings on either side, and the caudal extremity of the males of both species are alike in the number and arrangement of the papillæ. The measurements of *Filaria nitidulans* (males 20 mm., females 32 mm.) are, however, far in excess of the measurements for *Physocephalus sexalatus*, and the position of the vulva of *Filaria nitidulans* is stated as "directly above the anus," while the vulva of *Physocephalus sexalatus* is slightly posterior of the middle of the body. Ciurea (1912), who has recently reexamined Schneider's material, was unable to determine the location of the vulva of *F. nitidulans*. He gives, however, a summary of the differences between *Filaria nitidulans* and *Physocephalus sexalatus*, proving conclusively that they belong to different species, although he considers that *Filaria nitidulans* should be included in the genus *Physocephalus*. Stossich (1897b), following Von Drasche's (1884a) suggestion, considered the worms identical. He listed *Tapirus americanus* as a host of *Physocephalus sexalatus* and combined Molin's (1860b) measurements of *P. sexalatus* with Schneider's (1866a) measurements of *Filaria nitidulans*.

DISTRIBUTION OF ARDUENNA STRONGYLINA AND PHYSOCEPHALUS SEXALATUS IN THE UNITED STATES.

Of nine lots of *Arduenna strongylina* collected in various parts of the United States and now deposited in the helminthological collection of the Bureau of Animal Industry, only two have been found not to contain examples of *Physocephalus sexalatus*, and both of these lots contain only a few specimens. The distribution of *Arduenna strongylina* is therefore similar to that of *Physocephalus sexalatus*, since the latter species, according to the writer's experience, is practically always associated with the former.

To determine the distribution of these parasites and the frequency of their occurrence in the United States the literature was searched for references to *Spiroptera strongylina*. Four such references were found, as below; in most cases *Physocephalus sexalatus* was probably also present but not recognized.

1. Curtice (1892g), in a list of parasites infesting domestic animals and man in the United States, includes the following entry: "*Spiroptera strongylina* Rud. Host, *Sus scrofa domestica*. Location, stomach," followed by the remark, "Is often found with the food and attached to the walls." Specimens No. 2058 of the helminthological collection of the Bureau of Animal Industry were collected and identified by Curtice as *Spiroptera strongylina*. These specimens have been examined by the writer, who verified Dr. Curtice's identification. A few examples of *Physocephalus sexalatus* were also present.

2. Stiles and Hassall (1894e) include *Spiroptera strongylina* in their preliminary catalogue of the parasites in the collection of the United States Bureau of Animal Industry. They report the parasite as common. The specimens referred to by them (No. 2057 of the bureau collection) have been reexamined by the writer, and many specimens of *Physocephalus sexalatus* were found with the specimens of *Arduenna strongylina.* Stiles and Hassall's specimens were collected at Benning, D. C.

3. Francis (1894a) reported *Spiroptera strongylina* in a list of parasites collected by him in Brazos County, Tex. It is reported as common. The specific name is followed by an interrogation point in parenthesis to indicate the author's doubt as to the correctness of the identification. Considering the inaccuracy of the descriptions of *Arduenna strongylina,* then available, it is not to be wondered that Francis, noticing the discrepancies between the descriptions and the anatomical features seen in his specimens, should question the identification. On the other hand, it is quite possible that the specimens collected by Francis were *Physocephalus sexalatus,* or included this species.

4. Kaupp (1910) reported the occurrence of *Spiroptera strongylina* in hogs raised in the Missouri Valley. His article is illustrated with original drawings, one of which shows the caudal end of the female with the vulva apparently on the right side, a little anterior of the anus.

For the sake of additional data, letters were sent to the inspectors in charge at some of the principal slaughterhouses of the United States, requesting information in regard to the occurrence of *Spiroptera strongylina* in hogs. Replies were received from South Omaha, Chicago, St. Louis, and Kansas City. The inspector in charge at South Omaha reported that fully 80 per cent of the hogs examined were infested. It was reported from St. Louis that "the worms occur in considerable numbers in the mucous coating of the stomach." The parasite is reported as very frequent in hogs slaughtered at Kansas City; out of 1,450 hogs examined, 1,052 were infested. In some stomachs as many as 140 worms were collected. From Chicago it was reported that 1,000 hogs had recently been examined, and 690 were found infested. The worms were found on the surface of the mucous membrane or attached by the head. Several hundred specimens obtained by scraping the mucosa from the stomachs of a number of infested hogs were received from this city. These worms were found to be *Arduenna strongylina* and *Physocephalus sexalatus.*

Reports from slaughterhouses regarding the occurrence of parasites are of but little value in determining the localities infested by a given parasite, as the animals slaughtered are received from widely scattered sections of the country. Enough data have been gathered, however, to warrant the assertion that the parasites occur throughout the middle and southwestern (and probably eastern) United States. Specimens have been collected by Hall in 1908 from a hog kept at Bethesda, Md., in all probability of eastern origin. They have also been collected by Kilborne at Washington, D. C., and by Stiles and Hassall at Benning, D. C.; in the latter case, however, it is possible that the host animal had been shipped to the local slaughterhouse from a Western or Central State.

RELATIVE FREQUENCY OF THE TWO SPECIES.

That *Physocephalus sexalatus* occurs less abundantly than *Arduenna strongylina* in American swine is indicated by the following data:

All the worms contained in a bottle of specimens forwarded from Chicago were sorted out by species and sex. The bottle contained 744 specimens. Of these, 599, or approximately 80 per cent, were *Arduenna strongylina,* and the remaining 145, or 20 per cent, were *Physocephalus sexalatus.* Of the 599 specimens of *Arduenna strongylina,* 399, or 56 per cent, were females, and 260, or 44 per cent, were males. A smaller percentage of males was found among the specimens of *Physocephalus sexalatus.* Of the 145 specimens found, 69 per cent were females and 31 per cent were males.

LESIONS ASSOCIATED WITH ARDUENNA STRONGYLINA, ARDUENNA DENTATA, AND PHYSOCEPHALUS SEXALATUS.

From an economic standpoint these three species are probably of considerable importance. Prior to 1899 it was not considered that *Arduenna strongylina* was especially injurious to swine. Neumann (1892a), in mentioning that *Spiroptera strongylina* caused small submucous tumors of the stomach and that no morbid disturbances were attributed to it, summed up the general opinion of the time regarding the economic importance of the parasite. More recent reports, however, indicate that these parasites should be regarded as the possible etiology of serious gastric disorders.

Von Rátz (1899d) found *Spiroptera strongylina* very common among swine in Hungary, and attributed to this parasite several epizootics of a rather serious nature, in one of which, out of a herd of 230 sows, 21 were seriously affected and 6 died. Some of the symptoms were described as follows:

> The diseased sows suffered from loss of appetite, eating very little and in the worst cases finally refusing all food; on the other hand, they drank water excessively and were very restless, continually pawing the ground.

Describing the post-mortem lesions seen in the stomach, Von Rátz says:

> At the pyloric end the mucous membrane was covered with a thick, lamellous, firmly adhering pseudomembrane, which upon being removed revealed a superficial loss of tissue of the mucous membrane. Under the mucous membrane lay numerous

Spiroptera strongylina fastened partly in the stomach wall, partly in the pseudomembrane. In addition to these lesions, dark red spots the size of a penny were to be seen, corresponding to which were numerous openings the size of a needle prick, through which projected the bodies of the nematodes.

While no data are at hand regarding the effect of *Arduenna dentata* on its host, in view of its close similarity with *Arduenna strongylina* and the fact that both species are parasitic in the stomach, it may be assumed that the former species is as injurious as the latter.

Railliet and Henry (1911b) report that the stomach of a sow from Madagascar from which specimens of *Physocephalus* were collected, presented a very intense gastritis with a quantity of small elevations on the mucosa.

The information and material supplied by the inspectors of this bureau have shown that lesions of a nature similar to those described by Von Rátz are frequently associated with the presence of *Arduenna strongylina* in this country.

The inspector in charge at South Omaha reported that "Ten per cent of the affected stomachs show a highly inflamed zone surrounding the infested area, and in a few instances considerable ulceration exists." The inspector in charge at St. Louis was of the opinion that "they produce no apparent lesions." The inspector in charge at Chicago forwarded, in addition to the loose specimens already mentioned, several pieces of hogs' stomachs showing the worms in situ. The heaviest infestations were found in portions from the pyloric end of the stomach, which in one instance presented the following appearances: A piece of stomach from the pyloric end about 21 cm. wide by 20 cm. long contained a cluster of worms buried in a glairy mucous mass of yellowish color firmly attached to the normal mucous membrane, and forming, in the opinion of pathologists in the Pathological Division of this bureau, to whom the tissues were referred, a pseudomembrane of necrotic tissue. Several such worm clusters were observed on the portion examined, the worms in nearly every case being buried in a mass of mucus, and appearing as bright red lines in the yellowish mass. (See Pl. I.) In places the necrotic tissue had apparently sloughed off, leaving deep, red, depressed areas of irregular shape. These areas varied in size from a few millimeters to 2 or 3 centimeters in diameter. The same lesions could be observed under the necrotic tissue when this had been removed with forceps. The condition was described by one of the pathologists as "undoubtedly ulcerous."

It was suggested by the pathologists who examined the material that the pseudomembranes might have been caused by *Bacillus necrophorus* gaining an entrance to the submucosa as the result of the piercing of the mucous membrane by the parasitic worms; examinations of scrapings from the stomach lesions revealed a few specimens of the bacillus. As explained by Mohler and Morse (1904), this bacillus is normally found in the stomachs of hogs and other animals, and while under ordinary circumstances it has no pathological effect, if enabled through some lesion to the mucous membrane to gain access to impaired tissue, its proliferation results in the sloughing of the mucous membrane and the formation of ulcers.

Mohler and Morse (1904), describing necrobacillosis of the digestive tract, state: "The necropsy in such cases revealed hemorrhages and erosions in the stomach, but no areas of coagulation," an accurate description of the conditions found by the present writer. The characteristic odor described for lesions of *Bacillus necrophorus* was only faintly present, being modified perhaps by the boric acid with which the specimen was sprinkled and which may account for the paucity of the parasitic flora found.

How deeply *Arduenna strongylina* is capable of penetrating into the submucosa was well shown in one of the specimens forwarded from Chicago. A piece of the cardiac portion of the stomach contained a worm 12 mm. long which had bored diagonally into the mucosa to a depth of 10 mm., only the caudal end projecting above the surface. The hole made was similar to a pin prick, a simile used by Von Rátz (1899d) in describing the lesions observed by him. Indeed Von Rátz's description is practically identical with the conditions found by the present writer.

The habit of boring into the mucosa characteristic of these parasites would seem an ideal method of inoculating the submucosa of the host with *Bacillus necrophorus* if any were present, and this, considered in connection with the conditions observed in infested stomachs, indicates that the worms may be the indirect cause of grave ulceration. Considered apart from their possible rôle as infective agents, the mechanical injury to the stomach walls due to the penetration of the worms in numbers would seem to be a serious factor even if the worms were unassociated with bacilli. Moreover, the livid red color of the worms in situ in the stomachs examined would seem to indicate that they feed on blood, an additional reason for regarding them as dangerous parasites. The whole question, however, of the pathogenicity of the parasites, and as to their relationship to the lesions observed, remains open for further investigation.

An examination of the stomach portions received showed specimens of *Physocephalus sexalatus* attached in the same manner as already noted for *Arduenna strongylina;* hence the former parasite may be considered only less dangerous than the latter, as it is less abundant.

LIFE HISTORY.

Nothing is known in regard to the development of the worms from the egg to the adult. The wide distribution, the frequency of the parasites, and the similarity of the eggshell to that of an ascarid, suggest the possibility that development occurs without an intermediate host. From the fact that the embryos are well developed in the uterus before oviposition, it would seem that but little time is required for incubation, and the thickness of the shell would indicate the necessity of the gastric juice of the host to dissolve the shell and liberate the embryo.

PREVENTIVE MEASURES.

In the absence of knowledge as to the life cycle of the parasites, no prophylaxis or treatment specially adapted to the case can be formulated. The following general prophylactic measures are suggested:

1. Hogs suffering from loss of appetite or failing to fatten under proper food and hygiene should be examined for evidence of infection by killing one or two and looking in the stomach for worms; or, where practicable, the feces of the entire herd may be examined microscopically.
2. Those swine found infested with stomach worms should be isolated from noninfested or presumably noninfested swine in clean pens, and the dung removed daily and mixed with quicklime or disposed of by carting it to places to which hogs do not have access.
3. The noninfested swine should not be allowed to remain in the same pens formerly occupied by the infested animals, but should have clean quarters. The old pens should be thoroughly disinfected with lime after removing the dung and burning over the ground where feasible.

MEDICINAL TREATMENT.

Youatt (1847c), referring to *Spiroptera strongylina,* recommends turpentine and salt with the food for treating these worms. Coal-tar creosote, gasoline, and copper sulphate have been found more or less efficacious in treating stomach worms (*Hæmonchus contortus*) in sheep, and similar treatment might be tried on pigs (see Bureau of Animal Industry Circular 102). Santonin and calomel, 3 grains each per hundred pounds of body weight, given after a fast of 12 to 16 hours, is another remedy which deserves trial.

Whatever drug is used should first be given in small quantities and tried on a few of the most heavily infested swine, the size of the dose being increased as occasion demands.

KEY TO THE ROUNDWORMS PARASITIC IN DOMESTIC SWINE.

The arrangement of the following key to the roundworms which have been reported by various authors as parasites of hogs is purely artificial and arbitrary and indicates nothing as to the systematic relationship of the different forms. A classified list of the roundworms of swine is given later on page 41.

Section.

Parasitic in alimentary tract.. 1
Parasitic in respiratory tract.. 16
Parasitic in other organs.. 17

1. Diameter of body at middle over 3 mm.. 2
Diameter of body at middle less than 3 mm.. 3

2. Anterior extremity furnished with a protractile proboscis covered with spines. Male 6 to 10 cm. long, 3 to 5 mm. in diameter. Female 20 to 35 cm. long, 4 to 9 mm. in diameter. Eggs, 87 to 100 μ long, subcylindrical, smooth, with 3 envelopes. In small intestine, usually attached to the mucous membrane.. *Gigantorhynchus hirudinaceus.*
Anterior extremity without protractile proboscis. Mouth with 3 prominent lips. Male 15 to 17 cm. long, 3 to 3.2 mm. thick. Female 20 to 25 cm. long, 5 to 5.5 mm. thick. Eggs oval, 66 μ long, thick-shelled, surface covered with mammillate projections. In small intestine, sometimes in biliary tract and pancreas.. *Ascaris suum.*

3. Less than 5 mm. in length.. 4
Over 5 mm. in length.. 5

4. Vulva anterior of middle of body. Ovoviviparous. Females 3 to 4 mm. long, 60 μ in diameter. Males 1.4 to 1.6 mm. long, 40 μ in diameter, with a short finger-like process on each side of the anal opening. Adults in small intestine, larvæ encysted in skeletal muscles.......... *Trichinella spiralis.*
Vulva posterior of middle of body. Females (parthenogenetic; parasitic males lacking) 3.75 mm. long, 80 μ in diameter. Eggs 45 μ long by 25 μ broad, with thin shells. In small intestine............. *Strongyloides suis.*[1]

5. Head covered with spines; separated from the body by a deep constriction. Male 15 to 25 mm. long. Female 22 to 31 mm. long. Eggs 70 μ long by 39 μ wide. In stomach.. *Gnathostoma hispidum.*
Head without spiny armature.. 6

6. Posterior end of body of female with relatively large rosette-like excrescence containing the hypertrophied uterus. Male 12 mm. long. Female 15 mm. long. In stomach .... *Simondsia paradoxa.*[2]
Posterior end of body of female without uterine rosette........................ 7

7. Anterior portion of body slender, like a whiplash, about twice as long as the thicker posterior portion. Male with single spicule. Male 33 to 40 mm. long. Female 34 to 50 mm. long. Eggs 52 to 56 μ long, ellipsoidal, with an opening at each pole closed by a plug-like operculum, and brownish in color. In cecum.. *Trichuris suis.*
Body continuous, not flagelliform anteriorly. Male with two spicules........ 8

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[1] While *Strongyloides papillosus* (= *Trichosoma papillosum* Wedl.) a parasite of sheep has frequently been reported for the pig, this is probably the result of confusion with *Strongyloides suis*. The *Strongyloides* of the pig is somewhat larger than the form found in sheep.

[2] Included by the present writer among the Filariidæ on account of the inequality of the spicules. Its position in this family is not, however, definitely established. See footnote on page 9, second paragraph.

Section.

8. Male with two equal or subequal spicules; tail with membranous bursa supported by paired rays and eggs with thin shells........................... 9

Male with two spicules of very unequal length; tail with lateral longitudinal bursal membranes supported by stalked pappillæ. Eggs with thin or thick shells.. 12

9. Mouth enlarged to form a buccal capsule....................................... 10

Mouth small; buccal capsule not present. Male 5 mm. long. Female 8 to 8.5 mm. long. Spicules 130 μ long. Vulva about 2 mm. from the tip of the tail. Eggs, 45 μ long by 36 μ wide. In stomach.........*"Strongylus" rubidus.*[1]

10. Buccal capsule broader than long, mouth bordered by a crown of numerous, small, pointed processes. Male 8 to 12 mm. long. Female 12 to 15 mm. long. Spicules slender, 1.13 mm. long. Vulva a short distance in front of anus, protuberant. Adults in large intestine, larvæ encysted in the wall of the large and small intestines, forming nodules..*Œesophagostomum dentatum.*

Buccal capsule spherical or elongated, border of mouth smooth................ 12

11. Buccal capsule spherical. Male 7 mm. long, 0.2 mm. thick. Female 8 mm. long, 0.3 mm. thick. Vulva prominent. In small intestine.
Globocephalus longemucronatus.

Buccal capsule elongated, oval. Male 4.4 mm. long, 0.38 mm. thick. Female 6.5 mm. long, 0.52 mm. thick. Spicules 590 μ long. Vulva sunken. In small intestine .... *Crassisoma urosubulatum.*

12. Anterior end of body supplied with numerous cuticular tubercles or shields.. 13

Anterior end of body without cuticular tubercles............................ 14

13. Male 30 to 50 mm. long by about 250 μ thick. Female 80 to 145 mm. long, 300 to 350 μ thick. Left spicule 16 to 17 mm. long; right spicule 140 to 180 μ long. Vulva 4 to 5 mm. from tip of the tail. Eggs 55 to 60 μ long by 32 to 36 μ wide. In the mucosa of the esophagus and pharynx.
Gongylonema scutatum.[2]

Male 14 to 50 mm. long, 175 to 195 μ thick. Female 37 to 40 mm. long (? or longer), 350 μ thick. Left spicule 4 to 5 mm. long, right spicule 84 to 110 μ long. Vulva about 2 mm. from the tip of the tail. Eggs 52 to 56 μ long by 32 μ wide. In the mucosa of the esophagus and pharynx.
Gongylonema pulchrum.

14. Body furnished anteriorly with six longitudinal lateral wings, three on each side, the middle wing of each three wider than the other two. Ridges of pharynx forming a simple spiral, breaking up into separate wings. Male 6 to 9 mm. long. Female 13 to 19 mm. long. Spicules 2.1 to 2.25 mm. long, and 300 to 350 μ long, respectively. Vulva anterior of the middle of the body. Eggs 34 μ long by 15 μ wide, with rather thick shells. In stomach.
Physocephalus sexalutus.

Anterior portion of body with a single longitudinal wing. Ridges of pharynx forming a continuous multiple spiral.................................. 15

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[1] *"Strongylus" rubidus* does not belong in the genus *Strongylus.* Its proper position is in the family Trichostrongylinæ. As yet, however, no genus has been established to which it may be assigned.

[2] Reported by Korzil (1877a) and Piana (1896b). According to Neumann (1894d), however, the measurements given by Korzil indicate that the species studied by him is *Gongylonema pulchrum,* Molin 1857. The measurements given by Piana (1896b) are, males 60 to 80 mm. long by 130 μ broad; females 80 to 145 mm. long, 600 μ broad. Except that *G. pulchrum* is smaller than *G. scutatum,* there is but little morphological difference between the two species. The species are considered identical by Railliet (1893a), although this view is not accepted by Neumann (1894d) and others. *G. scutatum* is normally a parasite of ruminants.

Section.

15. Male 10 to 15 mm. long. Female 16 to 22 mm. long. Long spicule 2.24 to 2.95 mm. in length, 5 to 6 times as long as the short spicule. Vulva somewhat anterior of the middle of the body. Eggs 34 to 39 μ long by 20 μ wide, with rather thick shells. In stomach.................*Arduenna strongylina.*

Male 25 to 35 mm. long, 700 to 800 μ broad. Female 40 to 55 mm. long, 1.1 to 1.2 mm. broad. Long spicule 3.75 to 4.23 mm. long. Short spicule 540 to 650 μ long. Vulva three-eighths of the distance from the anterior end. *Arduenna dentata.*

16.[1] Spicules about 4 mm. long, each terminated by a single hook. Vagina about 2 mm. long. Male between 12 and 25 mm. in length. Female between 20 and 50 mm. in length. Vulva near anus. Eggs between 57 and 100 μ in length and 39 and 73 μ in width. In trachea and bronchi..*Metastrongylus apri.*

Spicules 1.5 mm. long, each terminated by a double hook. Vagina about 500 μ long. Male between 12 and 25 mm. in length. Female between 20 and 50 mm. in length. Vulva near anus. Eggs between 57 and 100 μ in length and 39 and 72 μ in width. In trachea and bronchi. *Metastrongylus brevivaginatus.*

17.[2] Encysted in skeletal muscles, microscopic in size. Cysts slightly elongated, ovoid, long axis parallel to the muscle fibers, about 400 μ long by 250 μ broad. *Trichinella spiralis* (larvæ).

Free in peritoneal cavity, in kidneys, in ureters, in the bladder, or encysted in fat of kidneys or loins.. 18

18. Male under 40 mm. long.. 19

Male over 12 cm. long.. 20

19. Male 25 to 37 mm. long. Female 37 to 40 mm. long. Two spicules, equal or subequal, about 0.8 mm. long. Vulva less than 2 mm. from the tip of the tail. Eggs 100 μ long by 56 μ wide, with thin shells. In kidneys, ureters, and encysted in fat of kidneys and loins.................*Stephanurus dentatus.*

20. Male 14 to 40 cm. long, 4 to 6 mm. in diameter. Female 20 cm. to 1 m. long, 5 to 12 mm. in diameter. Spicule single, 5 to 6 mm. long. Vulva near the anterior end of the body. Eggs 64 to 68 μ long by 40 to 44 μ wide, thick-shelled, with pitted surface. In kidneys, ureters, peritoneal cavity, or bladder..*Dioctophyme visceralis.*[3]

Male 10 to 11 cm. Greatest diameter, 650 μ. Tail twisted in a loose spiral with a pointed end; 8 pairs of papillæ, 4 preanal and 4 postanal. Spicules unequal, the longer 215 μ long, 25 μ broad, with a membraneous extension 70 μ long. Short spicule 140 μ long, 52 μ broad. Female 20 to 21 cm. long. Vulva 600 μ from the anterior extremity. Anus 300 μ from the posterior extremity. Eggs ovoid, 45 by 26 μ when fully developed. Viviparous. Parasitic in the peritoneal cavity.........................*Setaria bernardi.*

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[1] Railliet and Henry, 1911, describe a new species, *Filaria bauchei*, found in the "lungs" of a hog slaughtered at Hué, Indo-China. The location of the parasite is not definitely known. The female alone was found. It is reported as 22½ cm. long, with a maximum diameter of 635 μ. The body is transversely striated, the striæ being 5 to 6 μ apart. Mouth unarmed, funnel-shaped, the cuticle thickened at the anterior end. Anus 155 μ from the posterior extremity; vulva 1.1 mm. from the mouth.

[2] *Gigantorhynchus hirudinaceus*, although normally located in the intestine, sometimes perforates the intestinal wall, in which case it may be found in the peritoneal cavity. (See No. 2 of this key, first paragraph.)

Ascaris suum may be found aberrant in various locations outside the digestive tract. Diagnostic characters for the identification of this species have already been given. (See No. 2 of this key, second paragraph.)

[3] Included by Von Linstow (1878a) among the parasites of the domestic hog, but its occurrence in this host is questionable.

CLASSIFIED LIST OF ROUNDWORMS PARASITIC IN DOMESTIC SWINE.

Specific descriptions are omitted from the following list as these have already been given in the key to the roundworms of swine. Arranged according to their respecive orders, families, and genera, the roundworms reported as parasitic in domestic swine are as follows:

Class Nemathelminthes: Cylindrical worms without a prebuccal ciliary apparatus provided with a variable nervous system, not forming a ventral chain. Generally dioecious.

Order Nematoda. Nemathelminthes: Provided with a complete digestive tube.

Family Angiostomidæ. Nematoda: Having two heterogenetic generations, one of free-living males and females and one of hermaphroditic or parthenogenetic forms which are parasitic.

Genus Strongyloides. Angiostomidæ: Parasitic form with mouth opening directly into the relatively very long subcylindrical esophagus. Vulva posterior of the middle of the body. Uterus double. Two ovaries. Free-living form with mouth opening into a vestibule or pharynx, followed by an esophagus whose anterior portion is fusiform and posterior portion globular.

Strongyloides suis.

Family Gnathostomidæ. Nematoda: Body furnished throughout its length, or only anteriorly, with chitinous blades or wings, serrated posteriorly. Head subglobular, covered with simple spines.

Genus Gnathostoma: With the characteristics of the family.

Gnathostoma hispidum.

Family Trichinellidæ. Nematoda: Esophagus consisting of a chain of single cells, the lumen of the esophagus passing through the center of each cell. Anterior portion of body containing the esophagus usually very slender; posterior portion containing the intestine and reproductive organs more or less swollen. One testicle, one ovary.

Subfamily Trichinellinæ. Trichinellidæ: Male without spicule. Female ovoviviparous. Adults in intestine of host produce larvæ which penetrate into the muscles, become encysted, and develop to maturity when the flesh of this animal is eaten by another animal.

Genus Trichinella. Trichinellinæ: Very small worms with capillary bodies. Progressively increasing in diameter posteriorly. Male with two conical posterior appendages forming a copulatory bursa. Vulva of the female in the anterior fifth part of the body.

Trichinella spiralis.

Subfamily Trichurinæ. Trichinellidæ: Male with spicule. Female deposits eggs characterized by the presence of an opening at each pole closed by a pluglike operculum. Eggs do not hatch until swallowed by a suitable host. Development, so far as is known, direct, without an intermediate host.

Genus Trichuris. Trichurinæ: Anterior portion of body very long and slender. Posterior portion of body containing the intestine and reproductive organs relatively thick and much shorter than the anterior portion. Posterior portion of male rolled dorsally into a spiral. Spicule surrounded by a prepuce-like sheath. Posterior portion of body of female slightly curved. Vulva near the beginning of the posterior portion of body...... *Trichuris suis.*

Family Filariidæ. Nematoda: Body long, filiform. Mouth surrounded with papillæ, or provided with two lips. Esophagus slender, without posterior bulb. Males with two unequal spicules (sometimes with a single spicule). Females with two ovaries. Vulva usually anterior of the middle of the body. Development often requires an intermediate host.

Genus Filaria. Filariidæ: Body long and slender, of nearly uniform diameter throughout; males considerably smaller than the females, with the tail hooked or curved in a spiral, sometimes furnished with lateral wings. Usually there are four preanal and a variable number of postanal papillæ. Spicules usually very different in shape and dimensions. Vulva more or less near the mouth. *Filaria bauchei.*[1]

Genus Setaria. Filariidæ: Head armed with a projecting peribuccal circle, deeply notched laterally, somewhat less indented dorso-ventrally, giving the impression of two teeth when seen laterally and of four teeth when seen at an angle. Tail of both sexes provided with two special appendices .... *Setaria bernardi.*

Genus Gongylonema. Filariidæ: Body filiform, slightly attenuated at either end. Anterior portion of body covered with numerous tubercles or shields formed by differentiation of the cuticle. In the median lines immediately behind the mouth, two semilunar depressions, one dorsal, the other ventral. Tail of male curved ventrally, supplied with two asymmetrical membranous wings. Vulva a short distance anterior of the anus..*Gongylonema scutatum.*[2]
Gongylonema pulchrum.

Subfamily Arduenninæ. Filariidæ:[3] Mouth with two lateral lips leading into a pharynx marked with cuticular ridges in the form of spirals or rings. Spicules unequal, the longer several times the length of the shorter. Four pairs of preanal papillæ. Eggs containing embryos at the moment of oviposition.

Genus Arduenna. Arduenninæ: Mouth leading into a cylindrical pharynx marked by ridges, forming a continuous multiple spiral. Esophagus continuous, nearly one-third of the length of the body. Spicules very long and very unequal. Tail twisted in a single coil. Bursa asymmetrical, supported by five pairs of papillæ.
Arduenna strongylina.
Arduenna dentata.

Genus Physocephalus. Arduenninæ: Body furnished anteriorly with six lateral wings arranged in a group of three wings each, on either side. The middle wing of each group is the widest. Pharynx cylindrical, relatively broad and long, marked with a simple spiral ridge on the inside, breaking up into separate rings and resuming the spiral at the posterior end............*Physocephalus sexalatus.*

Genus Simondsia.[4] Filariidæ: Female characterized by a tegumentary excrescence in the form of a rosette situated in the posterior part of the body and inclosing a prolongation of the intestine and a hypertrophied uterus .... *Simondsia paradoxa.*

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[1] This species, described by Railliet and Henry (1911), is provisionally included in the genus Filaria, *sensu lato*. As only one female was received, the material was insufficient for a more accurate generic diagnosis.

[2] See footnote 2, p. 39.

[3] See footnote, p. 9.

[4] Railliet and Henry (1911b) include Simondsia in the subfamily Arduenninæ, although Piana (1897e) describes the lips as dorso-ventral rather than lateral. In the structure of the esophagus, the number of preanal papillæ, and the inequality of the spicules Simondsia conforms to the description of the subfamily Arduenninæ.

Family Strongylidæ. Nematoda: Head with six more or less distinct circumoral papillæ. Males with a more or less well-developed bursa, each lateral lobe of which is usually supplied with six supporting rays. Spicules equal or subequal. Vulva may be anterior to the middle of the body, but is usually posterior. Oviparous. Development, so far as known, direct without intermediate host.

Subfamily Strongylinæ. Strongylidæ: Buccal capsule well developed. Eggs in the process of segmentation at the moment of oviposition. Embryo nearly always rhabditiform and development direct. Parasitic in the alimentary canal; exceptionally in the respiratory system.

Genus Œsophagostomum. Strongylinæ: Head 75 μ or more in diameter; buccal capsule small. Cuticle surrounding the mouth usually inflated to form a ringlike mouth collar. Bursa of male with two lateral lobes united by a smaller median lobe. Spicules more than 0.5 mm. long, slender, tubular, pointed; gubernaculum present, but not conspicuous.................... *Œsophagostomum dentatum.*

Genus Globocephalus. Strongylinæ: Buccal capsule cylindrical, larger in diameter than the thickness of the body, supported by two chitinous rings—one at the anterior end of the capsule, the other at the posterior end. The rings are joined by four chitinous longitudinal bands.......... *Globocephalus longemucronatus.*

Genus Crassisoma. Strongylinæ: Buccal capsule oval, smaller in diameter than the thickness of the body, supported by eight longitudinal thickenings of the cuticle, and a chitinous ring on the inside of the capsule.................. *Crassisoma urosubulatum.*

Subfamily Trichostrongylinæ. Strongylidæ: Buccal capsule absent or slightly developed. Eggs generally segmenting at the time of oviposition. Embryo rhabditiform and development direct. Parasitic in the alimentary canal.

Genus. Undetermined[1]...................... *Strongylus rubidus.*

Subfamily Metastrongylinæ. Strongylidæ: Buccal capsule absent or slightly developed. Eggs in various stages when oviposited. Embryo rhabditiform. Evolution unknown, perhaps requiring an intermediate host. Parasites of the respiratory or circulatory system.

Genus Metastrongylus. Metastrongylinæ: Mouth with six lips. Postero-lateral ray much reduced or absent. Dorsal ray and externo-dorsal rays slender, the others thick. Two very long spicules. Vulva close to the anus. Eggs with well-developed embryos. Parasitic in the bronchi and trachea.

Metastrongylus apri.
Metastrongylus brevivaginatus.

Subfamily not determined.

Genus Stephanurus. Strongylidæ: Anterior extremity truncated; mouth suborbicular, limited by a chitinous ring furnished with teeth. Caudal bursa of male with many lobes.

Stephanurus dentatus.

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[1] See footnote 1 on p. 39.

Family not determined.[1]

Genus Dioctophyme. Nematoda: Body cylindrical, mouth without lips, surrounded by papillæ. Male furnished with a filiform spicule. Female with a single ovary. Vulva in the anterior part of the body .... *Dictophyme visceralis.*

Family Ascaridæ. Nematoda: One lip median, dorsal; two submedian, ventral. Relatively thick forms. Males provided with two spicules. Females with double ovary.

Genus Ascaris. Ascaridæ: Furnished with three strong lips, the lateral sides of which are generally toothed. Males with two equal or subequal spicules and numerous papillæ anterior and posterior of the anus. Vulva located anterior of the middle of the body. Eggs globular or ellipsoidal, usually surrounded by an albuminous envelope. In process of segmentation at the time of oviposition .... *Ascaris suum.*

Order Acanthocephala. Nemathelminthes without mouth or digestive tube. Furnished with a protractile proboscis armed with hooks.

Family Gigantorhynchidæ. Acanthocephala: Body large and annulated; tæniaform. Hooks of the proboscis with two roots and covered with a transparent layer of chitin. Lemnisci lengthened into the form of rounded bags and having a central canal.

Genus Gigantorhynchus; with the characteristics of the family.
Gigantorhynchus hirudinaceus.

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[1] *Dioctophyme visceralis* although commonly included in the family Strongylidæ does not conform to all the characteristics of this family. It more closely resembles the Filariidæ as pointed out by Railliet and Henry (1909a). Probably it should be placed in a family by itself, but the question is open to further study.

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U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ANIMAL INDUSTRY.—BULLETIN 159.

A. D. MELVIN, CHIEF OF BUREAU.

FEEDING BEEF CATTLE IN ALABAMA.

I. Winter Fattening on Cottonseed Meal, Cottonseed Hulls, Corn Silage, and Johnson-Grass Hay.
II. Wintering Steers followed by Summer Fattening on Pasture.
III. The Value of Shelter for Fattening Cattle in Alabama.
IV. Early Compared with Late Fattening of Steers on Pasture.

BY

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AND

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LETTER OF TRANSMITTAL.

UNITED STATES DEPARTMENT OF AGRICULTURE,
BUREAU OF ANIMAL INDUSTRY,
Washington, D. C., July 10, 1912.

SIR: I have the honor to transmit herewith, and to recommend for publication in the bulletin series of this bureau, a manuscript entitled "Feeding Beef Cattle in Alabama," by Messrs. Dan T. Gray, professor of animal industry in the Alabama Polytechnic Institute, and W. F. Ward, junior animal husbandman in the Animal Husbandry Division of this bureau.

This bulletin presents further results of the investigations in beef production which have been carried on during the past seven years by the bureau in cooperation with the Alabama Experiment Station, former publications being Bulletins 103, 131, and 147. The work is being continued and other problems relative to the feeding of beef cattle in the South are being studied.

Respectfully,
A. D. MELVIN,
Chief of Bureau.

Hon. JAMES WILSON,
Secretary of Agriculture.

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INTRODUCTORY NOTE.

Among the facts of importance demonstrated in this bulletin are (1) the outstanding value of a ration of cottonseed meal and cottonseed hulls as a standard beef-making ration in Alabama when fed in winter; (2) the small necessity for shelter for beef cattle in Alabama; and (3) the great importance of the use of pasture for cattle when fed a summer ration of cottonseed cake. The authors have opened up an additional field for the use of pasture by their investigations of the relative value of short and long period feeding on summer pasture.

In this connection I take the opportunity again to point out the importance of these investigations not only to Alabama and other parts of the South but to the entire country as well. This work is laying the foundation for rational and profitable beef production under southern conditions and will grow in influence with the advance of the boll weevil and the eradication of the Texas-fever cattle tick. In this respect it will be worth far more to the South than the entire amount of the appropriation which makes it possible.

The importance of the work to the country at large lies in the fact that every square mile freed from ticks opens up just that much more territory to beef production and tends to offset the restriction of the western range by settlement, which in turn has already greatly restricted the western cattle output. With the extermination of the ticks will come a demand for information on how to feed beef cattle profitably, and that demand, I believe, can be met very largely by the results of these investigations. Prof. Gray and his assistants are demonstrating that cattle can be fed in Alabama at a cost far below that common in the corn belt, and this often with inferior, underbred, or even scrub cattle. If such results can be obtained with cattle which are seldom more than half or three-quarters pure, what may we not in reason expect with the improvement in breeding which will surely follow the eradication of the tick?

The United States faces a beef-cattle shortage. The cattle ranges of the West are every year being diminished in area by settlement. In the South, east of the Mississippi River, are enormous areas of practically idle land, suitable for pasture, where beef cattle can and should be raised and fattened. Is it too much to predict that in this section of our country will come the next great expansion of the beef-producing business in America?

GEORGE M. ROMMEL,
Chief of Animal Husbandry Division.

FEEDING BEEF CATTLE IN ALABAMA.

I. WINTER FATTENING OF STEERS ON COTTONSEED MEAL, COTTONSEED HULLS, CORN SILAGE, AND JOHNSON-GRASS HAY.

INTRODUCTION.

Cottonseed meal and cottonseed hulls, the two feeds which in the past have been used almost exclusively during the winter months for fattening cattle in the South, have advanced in price very materially during the last three or four years. This advancement in price has forced the southern farmers to seek feeds with which to supplement the cottonseed meal and hulls. In the experiment here reported, silage and Johnson-grass hay were used as supplementary feeds to the hulls. Cottonseed meal was the only concentrated feed employed.

Since the inauguration of the cooperative beef work by the Bureau of Animal Industry and the Alabama Experiment Station some results have been published relative to winter fattening of steers,[1] but silage and Johnson-grass hay were not introduced into any of the former rations. It should be understood that this bulletin is only a report of the progress of the cooperative beef work, as the experiments are being continued.

OBJECT OF THE EXPERIMENT.

This experiment was planned with the following objects in view:

1. To determine the profit, if any, in fattening a good grade of cattle in the winter time on high-priced feeds.

2. To compare a ration of cottonseed meal and hulls alone with a second ration of cottonseed meal, hulls, and silage, and with a third ration of cottonseed meal, hulls, and Johnson-grass hay.

The steers were divided into three lots of 20 in each, and were given the following feeds:

Lot 1.—Cottonseed meal, cottonseed hulls, corn silage.

Lot 2.—Cottonseed meal, cottonseed hulls, Johnson-grass hay.

Lot 3.—Cottonseed meal, cottonseed hulls.

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[1] See Bureau of Animal Industry Bulletin 103.

THE CATTLE.

The cattle were better than the average cattle of the South. They were all purchased in Sumter and neighboring counties during the fall of 1909, and were the best of a herd of about 300 head of improved cattle. None of them was purebred, but all had been graded up by the use of Hereford, Aberdeen-Angus, and Shorthorn sires. They varied from 2 to 3 years in age. The average weight of each animal at the beginning of the test was approximately 830 pounds, so they were larger than the average southern cattle. The increased size was due to the improved beef blood.

As these cattle were better than the average cattle of the State, they cost more in the fall than is usually paid for Alabama cattle. They were valued at 3¼ cents a pound when the test began, December 1, 1909.

METHOD OF CONDUCTING THE WORK.

The cattle were fed under average farm conditions. Mr. F. I. Derby, a farmer and stockman of Sumter County, Ala., agreed to cooperate with the Bureau of Animal Industry and the Alabama Experiment Station in this work, and the feeding was all done upon his farm. Mr. Derby furnished the cattle and the feed, and the work was planned and the feeding carried on under the supervision of the authors of this bulletin. Mr. J. W. Ridgway was stationed upon the farm and had personal supervision of the experiment.

No artificial shelter was provided for the cattle and as no trees were in the feed lots, they did not even have the protection which trees afford. They were fed in the open fields, as no shelter is needed in Alabama for mature fattening cattle. As Mr. Derby's main object in feeding cattle is to enrich his farm, the cattle were fed on areas which were to be subsequently planted in either cotton or corn. The cattle were fed upon fields consisting of about 10 acres of land to each lot of 20 cattle. While no account was kept of the amount of manure made, still it is known from subsequent work that the 60 head of cattle made at least 1 ton of manure each day, or 84 tons for the whole feeding period of 84 days. The manure, of course, added very much to the fertility of the land upon which it was dropped.

Many of the clay soils of the State would be ruined by tramping if the cattle were permitted to stay on them during the wet winter weather. The soil of Mr. Derby's farm is a light, sandy one, so the tramping of the cattle did not injure it materially. However, since this work was done, Mr. Derby has come to the conclusion that the winter tramping injures even a sandy soil, so hereafter he intends to feed in sheds and barns and haul the manure to the fields.

The steers were fed twice each day in open troughs located in the fields. The troughs were made so that they could be moved from place to place, thus insuring an even distribution of manure and avoiding too much packing of the soil in one place. The steers were fed in such amounts that the feed was all eaten within a few hours after it was put before them. Many feeders keep feed in the troughs constantly, but more satisfactory results are secured when the steers are required to clean the troughs after each meal. An abundance of pure water and salt was provided all the time.

At the close of the test the cattle were shipped to the Louisville market for sale. The experimental farm was located four miles from Whitfield, Ala., the nearest railroad station, and the cattle were driven to that point to be loaded on the cars.

PRICE AND CHARACTER OF FEEDS.

In work of this character the financial statement is not as satisfactory as could be wished, because the prices of feed as well as of cattle fluctuate considerably from year to year. Therefore the financial outcome of a particular experiment may not be duplicated by the cattle feeder owing to the different conditions under which he is operating. The prices listed in this bulletin were the actual prices paid for the feeds (except what was raised on the farm) and the actual prices realized for the cattle. This test was conducted during the winter of 1909–10; prices have not changed materially since that date. The following were the prices of the feeds, that produced on the farm being estimated at local rates:

	Per ton.
Cottonseed meal	$26.00
Cottonseed hulls	7.00
Johnson-grass hay	11.00
Silage (produced on farm)	2.50

All of the above feeds were of good quality. The Johnson-grass hay had been cut at the proper stage and was of excellent quality. The cattle ate it with considerable relish. The silage, after the first few days, was also of good quality as far as brightness and taste were concerned. The corn from which the silage was made did not have a heavy development of ear as the stand was thick and the planting was not made until June. Probably 30 bushels of corn to the acre would have been secured if it had been gathered. The cottonseed meal was fresh, bright, and of a high grade.

PRELIMINARY FEEDING.

Some of the steers were bought as early as November 1, 1909. Mr. Derby was getting his cattle together for winter feeding, so the experimental steers were placed in the feed lots with the general herd of feeding cattle until conditions were ready for the experiment to begin. On November 6 the cattle were all started on a small amount of cottonseed meal and hulls. This amount was gradually increased and they were receiving a full ration of the meal and hulls by November 15. This full feeding of cottonseed meal and hulls was continued until the experimental work began. On December 1 the 60 steers to be used in the experimental work were selected from the general herd of probably 300 steers; they were divided into three lots of 20 steers each, tagged, weighed, and placed in their respective fields, and the experiment proper was begun. The period previous to December 1 was considered a preliminary period. This period was introduced so that the cattle would have an opportunity to become accustomed to the surroundings and the feeds before the inauguration of the test.

DAILY RATIONS.

Many farmers injure their cattle and get them "off feed" by increasing too rapidly the cottonseed-meal part of the ration. These cattle had been in a preliminary feeding period for 24 days before the real test began, yet each steer was fed only 4 pounds of cottonseed meal daily at the inauguration of the experiment, December 1. Of course the amount was increased from time to time as the cattle would take it without scouring, but at no time did the steers receive more than 8 pounds of cottonseed meal daily. Many farmers would have had these steers on a daily ration of 10 pounds of cottonseed meal within 10 days after the feeding began. Scours, dizziness, stiffness, and occasional cases of blindness are almost sure to follow a heavy feeding of cottonseed meal. In the event of such troubles occurring the feeder is often compelled to sell under unfavorable circumstances, as the steers can not be held profitably. When they are marketed under such circumstances, the buyer is almost sure to discriminate against them because of their poor condition, and they consequently sell at a disadvantage when offered to the packer or butcher.

The following table outlines, by periods of 28 days each, the amount of feed given each steer daily:

TABLE 1.—*Average daily ration for each steer, by 28-day periods.*

Period	Lot 1.			Lot 2.			Lot 3.	
	Cottonseed meal.	Cottonseed hulls.	Corn silage.	Cottonseed meal.	Cottonseed hulls.	Johnson-grass hay.	Cottonseed meal.	Cottonseed hulls.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
First 28 days....	4.64	14.88	22.57	4.64	13.58	9.43	4.64	26.53
Second 28 days..	6.00	15.27	19.49	6.00	15.11	8.87	6.00	29.43
Third 28 days...	7.73	24.79	([1])	7.73	14.21	7.03	7.73	23.96

[1] No silage fed during this period.

During the first 28 days each steer received an average of only 4.64 pounds of cottonseed meal each day. The cattle feeder would not, as a rule, expect to secure good gains when the daily allowance of cottonseed meal was only 4.64 pounds, but the data show that these animals made excellent gains during the first 28 days. During the first period each steer in lot 1 (the silage-fed lot) received 14.88 pounds of cottonseed hulls and 22.57 pounds of corn silage each day along with the 4.64 pounds of cottonseed meal. The cottonseed meal was sprinkled over the hulls and silage and thoroughly mixed by hand. During the first period of 28 days each steer in lot 3 (the lot to which nothing was fed except cottonseed meal and hulls) ate 26.53 pounds of cottonseed hulls along with the 4.64 pounds of meal. At the end of the test, when the cottonseed meal was increased to 7.73 pounds daily for each steer, as many pounds of hulls were not consumed as at the beginning, so the daily allowance was cut down to 23.96 pounds for each steer. In lot 2 (the lot in which Johnson-grass hay was used to supplement the cottonseed meal and hulls) each steer, during the first period, ate 13.58 pounds of hulls and 9.43 pounds of the hay each day along with the 4.64 pounds of cottonseed meal. They were given as much hay each day as they would clean up. The hay was fed in racks, and none of it was trampled under foot and wasted.

During the second period of 28 days each steer ate an average of 6 pounds of cottonseed meal each day. With the exception of a small increase the roughage part of each ration was maintained practically as it was in the first period. Each steer in lot 3 ate practically 30 pounds of cottonseed hulls each day. The average cattle of the South, which are not as large as the ones used in this test, will not consume 30 pounds of hulls per steer per day. In some former beef-feeding work done by this Bureau and the Alabama Experiment Station[1] steers which averaged 816 pounds in weight at the close of the test ate only 19.9 pounds of cottonseed hulls daily.

Unfortunately for the test and the cattle, the supply of silage lasted only 56 days, so no silage was fed the steers in lot 1 during the last period of 28 days. Cottonseed hulls replaced the silage. During the last period each steer ate 7.73 pounds of cottonseed meal daily. They would have eaten a larger amount if it had been placed before them. The roughage part of the ration was decreased as the amount of cottonseed meal was increased. The steers themselves regulated the amount of roughage, as they were given only as much as they would clean up at each meal.

The above table should be closely studied by the cattle feeder. There is no doubt that the average southern farmer feeds too much cottonseed meal to his fattening cattle. When the allowance of meal is kept down to a reasonable amount, the cattle will feel better and make gains more economically than when 9 to 10 pounds are fed to each steer daily. At the same time the owner will not be forced to sell at unfavorable times because of scours and sickness.

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[1] See Bureau of Animal Industry Bulletin 103.

DAILY AND TOTAL GAINS.

The gains as given here are not fictitious in any sense. No "fill" is included, as the cattle had been on feed for 24 days before the test began. The gains would have been considerably larger if the "fill" had been included.

TABLE 2.—*Average weights and gains.*

[Dec. 1, 1909, to Feb. 23, 1910, 84 days.]

Lot.	Number of steers.	Ration.	Average initial weight of each steer.	Average final weight of each steer.	Average total gain of each steer.	Average daily gain of each steer.
			Pounds.	*Pounds.*	*Pounds.*	*Pounds.*
1	20	Cottonseed meal, cottonseed hulls, corn silage..	811	962	151	1.80
2	20	Cottonseed meal, cottonseed hulls, Johnson-grass hay..................................	820	949	129	1.54
3	20	Cottonseed meal, cottonseed hulls..............	851	995	144	1.71
		RESULTS FOR FIRST 56 DAYS—WHILE SILAGE WAS FED.				
1	20	Cottonseed meal, cottonseed hulls, corn silage..	811	915	104	1.86
2	20	Cottonseed meal, cottonseed hulls, Johnson-grass hay..................................	820	900	80	1.43
3	20	Cottonseed meal, cottonseed hulls..............	851	957	106	1.89

All of the cattle made satisfactory but not unusual gains. In the first part of Table 2 it is seen that the silage-fed steers (lot 1) made the largest gains, making an average daily gain of 1.8 pounds per steer for the whole period of 84 days. In the lower part of Table 2 are found the results of the first 56 days of the test, or the period when corn silage was fed to the cattle in lot 1. When the second part of the table is studied, it is seen that the cattle which ate silage did not make as large daily gains as did those which were fed nothing but cottonseed meal and hulls. During the first 56 days each steer in lot 1 (the silage lot) made an average daily gain of 1.86 pounds, while during the same period each steer in lot 3 (cottonseed meal and hulls only) gained 1.89 pounds each day. However, the reader should not come to the conclusion that the daily gains measure the success of a feeding operation altogether. It is, of course, necessary for good gains to be secured, but the final profits are not determined entirely by the daily gains. Other factors, such as the price of the feeds and the selling price of the cattle, must be taken into consideration.

The cattle which were fed a partial ration of Johnson-grass hay made the least satisfactory gains, making a daily gain per steer of only 1.54 pounds during the whole period of 84 days. As far as gains were concerned, the Johnson-grass hay proved to be unsatisfactory, as cottonseed meal and hulls produced greater gains when fed alone than when the two were combined with Johnson-grass hay. The hay was of good quality and the cattle ate it with considerable relish. Oftentimes Johnson grass is cut at such a late stage of maturity that it is stiff, woody, and unpalatable, but the hay used in this test was cut and harvested at the proper stage.

The supply of silage was exhausted at the end of 56 days, so this lot of cattle (lot 1) was continued to the end of the test on cottonseed meal and hulls, the hull part of the ration being increased sufficiently to take the place of the silage. After the feeding of silage was discontinued the cattle still continued to make good gains, as each steer made a gain of 47 pounds during the last 28 days of the test. During this same period each steer which was eating Johnson-grass hay (lot 2) made a gain of 49 pounds, while each steer in lot 3 gained only 38 pounds. As a matter of fact, it was expected that but small gains would be secured after the discontinuance of the silage, but the change was made gradually and the steers did not seem to notice the substitution of hulls for the silage. Cottonseed meal and hulls make an extremely palatable combination of feeds; in fact, it is difficult to find a combination of feeds more palatable than a mixture of these two southern feeds.

At the end of the experiment the steers in lots 1, 2, and 3 averaged 962, 949, and 995 pounds, respectively, in weight; they made average total gains per steer of 151, 129, and 144 pounds in the respective lots.

QUANTITY AND COST OF FEED REQUIRED TO MAKE 100 POUNDS GAIN.

In work of this character the real value of a feed, or a combination of feeds, is measured by the number of pounds of feed required to make 100 pounds of gain in live weight. With this information the farmer can apply the knowledge to his own conditions and quickly determine what it would cost to make 100 pounds of gain on his own farm. The table following shows the quantity of feed required to make 100 pounds of increase in live weight and the cost of the gains under the conditions of this test. The price placed upon the feeds was their actual cost laid down on the farm. The silage, of course, was made on the farm, and on it was placed an estimated value of $2.50 a ton.

TABLE 3.—*Quantity and cost of feed required to make 100 pounds of gain.*

[Dec. 1, 1909, to Feb. 23, 1910, 84 days.]

Lot.	Ration.	Feed to make 100 pounds of gain.	Cost of feed to make 100 pounds of gain.
		Pounds.	
1	Cottonseed meal	341	$8.98
	Cottonseed hulls	1,020	
	Corn silage	781	
2	Cottonseed meal	399	11.47
	Cottonseed hulls	931	
	Johnson-grass hay	550	
3	Cottonseed meal	357	10.08
	Cottonseed hulls	1,554	
	Results for first 56 days—while silage was fed.		
1	Cottonseed meal	287	$7.98
	Cottonseed hulls	812	
	Corn silage	1,132	
2	Cottonseed meal	372	11.88
	Cottonseed hulls	1,004	
	Johnson-grass hay	641	
3	Cottonseed meal	280	8.80
	Cottonseed hulls	1,475	

When feeds are valued as previously stated it is seen that the silage-fed steers (lot 1) made the cheapest gains in both cases. When the whole period of 84 days is taken into consideration each 100 pounds of increase in live weight cost $8.98 when the silage was used, $11.47 when Johnson-grass hay supplemented the cottonseed meal and hulls (lot 2), and $10.08 when nothing was fed except cottonseed meal and hulls (lot 3). Johnson-grass hay proved to be the most expensive and unsatisfactory feed used. During the first 56 days, when silage was being fed, each 100 pounds of gain in lot 1 cost $7.98; the same gain cost $11.88 in lot 2 where Johnson-grass hay was used in place of silage, and $8.80 in lot 3 where cottonseed meal and hulls were fed alone. As far as economical gains were concerned the silage proved to be a valuable addition to the cottonseed meal and hulls, but money was lost when Johnson-grass hay replaced part of the cottonseed hulls, each 100 pounds of increase in weight costing just $3.08 more when the hay was fed than when cottonseed meal and hulls were fed alone.

By studying the second part of Table 3, it is seen (lot 1) that 287 pounds of cottonseed meal, 812 pounds of hulls, and 1,132 pounds of silage produced 100 pounds of increase in weight. When the meal and hulls were fed alone (lot 3) it is further seen that 280 pounds of meal plus 1,475 pounds of hulls produced the same number of pounds of increase in weight; therefore 1,132 pounds of silage saved 663 pounds of hulls, but at the same time caused the loss of 7 pounds of cottonseed meal; or, 1 ton of the silage actually saved $3.94 worth of hulls and cottonseed meal when hulls and meal were valued at

$7 and $26 a ton, respectively. Corn silage in this test was therefore worth $3.94 a ton. In the same way it is found that 641 pounds of Johnson-grass hay took the place of 471 pounds of hulls, but caused the loss of 92 pounds of cottonseed meal; or, 1 ton of hay proved to have a feeding value of only $1.31 when the meal and the hulls were valued as above. Johnson-grass hay in this test was therefore worth $1.31 a ton, whereas it cost $11 a ton. Ton for ton, silage was just three times as valuable as Johnson-grass hay when they were both used along with cottonseed meal and hulls for fattening cattle. Johnson-grass hay proved to be a poor feed for fattening purposes, while silage had an exceedingly high value when used for the same purpose. The cattle feeder can not, therefore, afford to use Johnson-grass hay along with cottonseed meal and hulls for fattening purposes, and this experiment tends to show that the majority of southern feeders can not use a more economical feed than silage for this purpose.

ADVANTAGES OF USING PURCHASED FEEDS.

The majority of our southern farmers object to buying cottonseed meal, hulls, and other feeds for beef cattle on the ground that the original prices of the feeds can not be realized after being fed to cattle. At the same time thousands of these same farmers buy cottonseed meal and use it as a commercial fertilizer, when experience and experiments all teach that the first use of the meal should be as a feed for some kind of live stock and the second use as a fertilizer in the form of barnyard manure. When the cottonseed meal is fed to live stock it is used twice, once as a feed and again as a fertilizer. Many of our best farmers feed cattle for no other reason than to obtain the barnyard manure, and are satisfied if they come out even on the cattle; the manure is well worth the expense of feeding.

In these experiments the cottonseed meal cost $26 a ton and the hulls $7 a ton, and we are satisfied that in every case these feeds realized, as a result of feeding to the cattle, much more than they cost; that is, an actual profit was made on each ton of the feeds and at the same time the manure was left on the farm. The meal and hulls, therefore, were no expense at all to the soil or to the succeeding crops.

VALUE OF BARNYARD MANURE.

The farmer who has lands which should be built up should feel that he has fed cattle at a profit when manure is obtained free above all other expenses, as this manure has an exceedingly high fertilizing value. Beef cattle should be more generally introduced because of the good they do in building up and maintaining soils. Under the present system of cotton farming the soils are becoming poorer and poorer. With the introduction of cattle the soil will begin to be built up. Director Thorne, of the Ohio Agricultural Experiment Station, has been making tests with barnyard manure for several years, applying the manure upon a plot of ground upon which was running a three years' rotation of corn, wheat, and clover. Eight tons of manure an acre were applied. The average yearly increase an acre, following the one application, was as follows:

Corn, 14.7 bushels, at 70 cents a bushel	$10.29
Corn stover, 744 pounds, at $6 a ton	2.23
Wheat, 8.36 bushels, at $1 a bushel	8.36
Wheat straw, 897 pounds, at $4 a ton	1.79
Clover hay, 686 pounds, at $12 a ton	4.12
Total value of 8 tons of manure	26.79
Total value of 1 ton of manure	3.35

He further states (Bulletin 183, Ohio Experiment Station) that the value of farm manure can be materially increased by balancing the manure with the addition of a carrier of phosphorus. The farm manures are too high in nitrogen as compared with the other elements. By balancing stable manure, the value of 8 tons was increased $12.20 after deducting the cost of the material used for the balancing of the manure. This is $1.53 a ton, and when added to the $3.35 above, brings the total possible value of each ton of manure up to $4.88. During a feeding period of 100 days each steer will produce at least 1½ tons of manure. This profit should be added to the feeding or direct profits.

The Arkansas Station (Bulletin 68) made a test to determine the value to each succeeding crop of growing peas in the corn, gathering the corn, and then grazing both the peas and the stalks by the steers. The steers were fed some cottonseed in addition to the grazing. As the result of this crop of peas and the grazing, the succeeding cotton crop was increased 626.5 pounds of seed cotton over the area where corn alone had been grown. A third lot was planted to corn, and the increase in corn, due to the pea crop and the grazing, was 14 bushels an acre.

FINANCIAL STATEMENT.

It must be remembered that the financial statements in this bulletin are based on the local conditions where the feeding was carried on. Should the conditions elsewhere be different, the results will also differ. The price of the cattle when put into the feed lot is one very variable factor. The feeders in this particular experiment cost 3¼ cents a pound. In another part of the State they might have cost more than they did in Sumter County, and in still a third part they might have cost considerably less. The financial statement will not be misleading if the reader bears in mind that it does not apply to all conditions.

The cattle, as previously noted, were bought in Sumter and neighboring counties for 3¼ cents a pound during the fall of 1909. They were fed on cottonseed meal and cottonseed hulls for 24 days before the test began. The test continued for 84 days, when the cattle were ready for sale and were shipped to the Louisville (Ky.) market, where all of the steers sold for $5.75 a hundredweight. It cost 65 cents a hundredweight to ship them to the market, so they are estimated in the financial statement at $5.10 a hundredweight. The $5.10 represents the price actually received on the farm.

Lot 1. Cottonseed meal, cottonseed hulls, corn silage:

By sale of 20 steers, 18,658 pounds, at $5.10 per hundredweight		$951.66
To 20 steers, 16,220 pounds, at 3¼ cents a pound	$527.15	
To 10,290 pounds cottonseed meal, at $26 a ton	133.77	
To 30,768 pounds cottonseed hulls, at $7 a ton	107.69	
To 23,554 pounds corn silage, at $2.50 a ton	29.44	
Total expense		798.05
Total profit		153.61
Profit per steer		7.68

Lot 2. Cottonseed meal, cottonseed hulls, Johnson-grass hay:

By sale of 20 steers, 18,411 pounds, at $5.10 per hundredweight		938.96
To 20 steers, 16,400 pounds, at 3¼ cents a pound	$533.00	
To 10,290 pounds cottonseed meal, at $26 a ton	133.77	
To 24,026 pounds cottonseed hulls, at $7 a ton	84.09	
To 14,185 pounds Johnson-grass hay, at $11 a ton	78.02	
Total expense		828.88
Total profit		110.08
Profit per steer		5.50

Lot 3. Cottonseed meal, cottonseed hulls:

By sale of 20 steers, 19,303 pounds, at $5.10 per hundredweight		984.45
To 20 steers, 17,020 pounds, at 3¼ cents a pound	$552.15	
To 10,290 pounds cottonseed meal, at $26 a ton	133.77	
To 44,755 pounds cottonseed hulls, at $7 a ton	159.09	
Total expense		845.01
Total profit		139.44
Profit per steer		6.97

The foregoing financial statement shows that all of the lots of steers were fed at a profit. The outcome was satisfactory. The greatest profit was made in lot 1, where silage was used. The smallest profit was made in lot 2, where the Johnson-grass hay was fed. The cattle in lots 1 and 3 sold at the same price and made practically the same total gains in live weight, but those in lot 1 had the advantage in that they had a cheap feed—silage—added to the basal ration of cottonseed meal and hulls. Each steer in lot 1 made a clear profit of $7.68, while each one in lot 3 made a profit of only $6.97. The steers which received Johnson-grass hay along with the cottonseed meal and hulls (lot 2) made a profit of only $5.50 each.

SLAUGHTER DATA.

Table 5 shows the total weight of each lot of cattle after allowing 3 per cent for shrinkage, the live weight at the Louisville market, the number of pounds each steer lost in shipment, the dressed weight at Louisville, and the per cent of dressed weight to live weight. The steers were driven 4 miles to a railroad, and, on account of delays, were in the cars 48 hours.

TABLE 5.—*Shipping weights and slaughter records.*

Lot.	Number of steers.	Total weight on farm.	Total weight at Louisville.	Average shrinkage per steer.	Total dressed weight at Louisville.	Average per cent dressed out by farm weights.	Average per cent dressed out by market weights.
		Pounds.	*Pounds.*	*Pounds.*	*Pounds.*		
1	20	19,235	17,685	77.5	9,926	51.6	56.1
2	20	18.980	17,615	68.3	9,736	51.3	55.3
3	20	19,900	18,325	78.8	10.164	51.1	55.5

The shrinkage on the road was rather great, but it should be remembered that there was a delay of several hours in shipment. Those cattle which were fed Johnson-grass hay (lot 2) lost the fewest pounds in weight. Each steer lost 77.5, 68.3, and 78.8 pounds in lots 1, 2, and 3, respectively; or, the silage-fed steers (lot 1) lost in transit 8.1 per cent of their weight, those in lot 2 (Johnson-grass lot) lost 7.1 per cent, while those in lot 3 (cottonseed meal and hulls) shrunk 7.9 per cent.

The steers in lot 1 (the silage-fed cattle) dressed out higher than the steers in lots 2 and 3, dressing 56.1 per cent by the market weights. The steers in lots 2 and 3 dressed, respectively, 55.3 per cent and 55.5 per cent.

SUMMARY.

TABLE 6.—*Summary of results.*

Item.	Lot 1.—Feed: Cottonseed meal, cottonseed hulls, corn silage.	Lot 2.—Feed: Cottonseed meal, cottonseed hulls, Johnson-grass hay.	Lot 3.—Feed: Cottonseed meal, cottonseed hulls.
	Pounds.	*Pounds.*	*Pounds.*
Average weight of steers at beginning, Dec. 1, 1909	811	820	851
Average weight of steers at close, Feb. 23, 1910	962	949	995
Average total gain of each steer for whole period of 84 days	151	129	144
Average daily gain of each steer for whole period of 84 days	1.8	1.54	1.71
Average daily gain of each steer for first 56 days while silage was fed	1.86	1.43	1.89
Average cottonseed meal fed daily per steer	6.1	6.1	6.1
Average cottonseed hulls fed daily per steer	15.1	14.3	26.6
Average silage fed daily per steer	21	....	....
Average Johnson-grass hay fed daily per steer	....	8.40	....
Cottonseed meal to make 100 pounds gain for whole period of 84 days	341	399	357
Cottonseed meal to make 100 pounds gain for first 56 days	287	372	280
Roughage to make 100 pounds gain for whole period of 84 days	[1] 781 [2] 1,020	[2] 931 [3] 550	[2] 1,554
Roughage to make 100 pounds gain for first 56 days while silage was fed	[2] 812 [1] 1,132	[2] 1,004 [3] 641	[2] 1,475
	Dollars.	*Dollars.*	*Dollars.*
Cost to make 100 pounds gain for whole period of 84 days	8.98	11.47	10.08
Cost to make 100 pounds gain for first 56 days	7.98	11.88	8.80
Cost of steers per hundredweight in fall	3.25	3.25	3.25
Selling price of steers in Louisville	5.75	5.75	5.75
Selling price of steers on farm	5.10	5.10	5.10
Profit per steer	7.68	5.50	6.97

[1] Silage. [2] Hulls. [3] Hay.

1. The steers which were used in this test were from 2 to 3 years old. They had all been graded up by the use of Aberdeen-Angus Hereford, and Shorthorn sires.

2. At the beginning of the test they averaged 827 pounds in weight. They were fed 84 days, and at the close of the test they averaged 967 pounds.

3. The 60 head of steers were divided into three lots and fed as follows:

Lot 1: Cottonseed meal, cottonseed hulls, corn silage. Lot 2: Cottonseed meal, cottonseed hulls, Johnson-grass hay. Lot 3: Cottonseed meal, cottonseed hulls.

4. For the whole period of 84 days average daily gains of 1.8, 1.54, and 1.71 pounds were secured in lots 1, 2, and 3, respectively.

5. During the first 56 days, when silage was fed in lot 1, average daily gains of 1.86, 1.43, and 1.89 pounds were secured in lots 1, 2, and 3, respectively.

6. For the whole period of 84 days it cost $8.98, $11.47, and $10.08 to make 100 pounds of gain in lots 1, 2, and 3, respectively.

7. For the first 56 days, when silage was fed in lot 1, it cost, respectively, $7.98, $11.88, and $8.80 to make 100 pounds of gain in lots 1, 2, and 3.

8. In the fall of 1909 the steers cost $3.25 per hundredweight. At the end of the test they were shipped to Louisville and sold for $5.75 per hundredweight.

9. Each steer in lots 1, 2, and 3 netted a clear profit of $7.68, $5.50, and $6.97, respectively.

10. Corn silage proved to be an exceedingly satisfactory addition to a basal ration of cottonseed meal and hulls, but Johnson-grass hay was an exceedingly unsatisfactory supplement when used in the same way.

II. WINTERING STEERS FOLLOWED BY SUMMER FATTENING ON PASTURE.

INTRODUCTION.

For several years this bureau, cooperating with the Alabama Experiment Station, has been studying the subject of wintering mature steers and subsequently fattening them in the summer on pasture. Some of the work has been published,[1] but the conditions surrounding the work herein published were altogether different from those of the previous work. In the first place, these cattle were of different age and quality from the ones used in the former experimental work. In the second place, the grass upon which these cattle grazed grew on a sandy instead of a lime soil. In the previous work the cattle were grazed upon lime soils with sweet clover (Melilotus) as the basal pasture crop during the early part of the grazing season. In the work published in this bulletin no sweet-clover pastures were available, as sweet clover does not occur upon the sandy soils of this region.

Two separate experiments are reported in this part of the bulletin, owing to the fact that two distinct types of cattle were used. The animals were divided into four lots, two of them composed of high-grade young cattle and the other two of common or scrub cattle fully a year older. The work was done in cooperation with Mr. F. I. Derby, of Sumter County, Ala., he furnishing the cattle and the feed and the Bureau of Animal Industry and the Alabama Experiment Station providing a trained man to carry on the experiment. Mr. J. W. Ridgway was located on the farm and had personal supervision of all of the experimental work.

OBJECT OF THE WORK.

This work was outlined with the following objects in view:

1. To study the problem of feeding steers during the winter months with a view to fattening them on pasture the following summer.
2. To determine the profits, if any, in supplementing sandy-soil pastures with cottonseed cake during the summer fattening process.
3. To study a common southern method of managing and fattening common or scrub cattle.

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[1] See Bureau of Animal Industry Bulletin 131.

Steers can be purchased cheaper during the fall of the year than at any other time, so many feeders prefer to buy in the fall. When cheap steers are so purchased, a common practice in the South is to "rough" them through the winter months as cheaply as possible, turn them on pasture the following summer, and sell them to the butcher at the end of the pasture season.

THE CATTLE.

The cattle were all bought in Sumter and neighboring counties, but those selected for lots 4 and 5 were an excellent grade of animals, all having Shorthorn or Aberdeen-Angus blood, while those placed in lots X and Y represented no particular breeding; they were, in fact, scrubs, or the common cattle of the neighborhood. The steers in lots 4 and 5 were from 20 to 24 months old when purchased, in the fall of 1909, and had attained an average weight of 616 pounds. The steers of lots X and Y were from 3 to 4 years old and weighed only 565 pounds each when the tests began, December 6, 1909. The cattle, both young and old, were dehorned as soon as they were brought to the farm.

The reader's attention should be called to the fact that while the results secured in lots 4 and 5 are comparable with each other, they are not in any way comparable with the results secured in lots X and Y. These are two separate experiments and are not comparable in any way.

THE PASTURES.

The soil upon which these steers grazed was of a sandy and sandy-loam character, such as is found in a cut-over pine district. A large proportion of the pastures were low, so that in rainy weather they became exceedingly wet. There was some sandy ridge land, however, in each pasture.

Carpet grass, lespedeza, broom sedge, and a small amount of Bermuda and *Paspalum dilatatum* constituted the plants that formed the pastures. Sweet clover (Melilotus), as before stated, does not grow in this region. They afforded an abundance of grass throughout the grazing season, but the growth was rank and very watery, as the frequent rains kept the pasture exceedingly wet during the whole test. No expense or time had ever been expended on these pastures except to build a wire fence around them. The plants mentioned above had come voluntarily after the pine woods were cleared away.

THE WINTER RANGE.

The steers of lots X and Y, after being dehorned and tagged, were turned out, December 6, 1909, in a tract of cut-over pine lands. Approximately 20,000 acres of land were in this tract, but it was not fenced, so the steers had the privilege of going practically anywhere in the southern part of Sumter County. This land had grown up during the previous summer with broom sedge, lespedeza, and other native grasses. When frost came the grasses were, of course, all killed, but still they afforded some grazing for the steers during the first part of the winter. During the latter part of the winter, when grazing is usually short, no little amount of Augusta vetch came up and furnished good grazing during the early spring months. This plant, more than anything else, perhaps, kept the steers from losing weight while on the range, as it gave good grazing in March and April. The steers evidently gained in weight during these two months. The steers were not taken off this range until April 23, 1910.

The young steers of lots 4 and 5 were not turned on the range.

PLAN OF THE FEEDING.

In order to give a clear idea of the nature of the work, the general plan of the feeding is outlined below:

TABLE 7.—*General plan of the feeding.*

THE YOUNG STEERS.

Lot.	Number of steers.	Winter feeding.	Summer fattening.
		(Dec. 6, 1909, to Mar. 31, 1910.)	(Apr. 2 to Aug. 26, 1910.)
4	18	Cottonseed meal and cottonseed hulls (one-half ration).	Pasture and cottonseed cake.
5	17	Cottonseed meal, cottonseed hulls, and Johnson-grass hay (one-half ration).	Do.

THE COMMON STEERS.

		(Dec. 6, 1909, to Apr. 23, 1910.)	(Apr. 23 to Sept. 2, 1910.)
X	28	Range only	Pasture and cottonseed cake.
Y	15	.....do	Pasture alone.

The general plan was to feed the steers of lots 4 and 5 sufficient feed to produce small gains throughout the winter months. They were a good class of cattle and young, so it was thought that it would pay to feed them liberally during the winter months. Accordingly a partial ration of cottonseed meal and cottonseed hulls was fed to the steers in lot 4, and those in lot 5 had some Johnson-grass hay added to the basal ration of cottonseed meal and hulls. No effort was made to fatten these young cattle during the winter; the object was to make only small gains and keep them in thriving condition. The fattening was to occur the subsequent summer, when they were on pasture.

The steers of lots X and Y were turned out as one lot on the range for the winter. These cattle being of poor quality, it was not thought profitable to give them high-priced feeds during the winter months, when they were to be fattened on pasture the following summer. As stated before, the range consisted of cut-over pine lands; they had the freedom of probably 20,000 acres of land.

The authors realize that this method of handling and feeding cattle during the winter is one that will soon go out of vogue on account of the fact that these large ranges will eventually be settled and fenced, but at the present time and under present conditions many farmers are so situated that they can profitably make use of these large tracts. These cattle received no attention at all throughout the winter months. In fact, only a few of them were seen during the whole winter. The following spring, March 21, they were brought up, weighed again, and turned onto the summer pasture for the summer fattening work. They were now divided into two lots and fed upon different feeds. The steers of lot X were grazed upon a pasture and received a small feed of cottonseed cake in addition to the pasture. The steers of lot Y were in a similar pasture and received nothing in addition.

No shelter except the trees was provided for the cattle in either the winter or summer time. They did not seem to suffer from the cold in the winter or from the heat in the summer. The summer pastures were abundantly provided with good shade trees and water.

While there were cattle ticks (*Margaropus annulatus*) in the pasture, yet the cattle were not permitted to become badly infested. A dipping vat was used to keep down heavy infestation. No cases of Texas fever developed.

The weight of each steer was secured at the beginning and the end of each test, and, with the exception of lots X and Y during the winter of 1909–10, the total weight of each lot was noted every 28 days. When the steers were sold, they were driven 4 miles to the shipping point at Whitfield, Ala.

CHARACTER AND PRICE OF THE FEEDS.

Local conditions determine to a large extent the farm prices of feeds. Any prices that might be assumed would not meet all conditions, but the following prices have been taken as a basis upon which to make financial estimates:

Cottonseed meal	per ton..	$26.00
Cottonseed cake	do....	26.00
Cottonseed hulls	do....	7.00
Johnson-grass hay	do....	11.00
Pasture, per steer	per month..	.50

All of the feeds were of good quality. The cottonseed cake, which was used in all of the summer feeding work, had been broken into nut size by the oil mill and sacked. As has been stated in a previous bulletin, this cake can be purchased in the large cake size, just as it comes from the press, for about $2 a ton cheaper than in the nut size.

Some feeders find that it pays to break the cake on their own farms. The cake is the same thing as cottonseed meal, except that it is not ground into a meal. There are several advantages in feeding cake in place of cottonseed meal, especially in summer feeding. A rain does not render the cake unpalatable; but it will often put the meal in such a condition that the cattle will not eat it. Again, no loss is incurred with the cake during windy days, whereas the meal, when fed in the open pasture, is sometimes wasted on account of the winds. Furthermore, the cake requires chewing before being swallowed, and therefore must be eaten very much more slowly than the meal, so when a number of steers are being fed together the greedy one has little chance to get enough cake to produce scours. In feeding cottonseed meal the greedy steer often scours on account of the fact that he can bolt the meal and get more than his share; this not only injures the steer but makes the bunch "feed out" unevenly.

THE WINTER FEEDING.

DAILY RATIONS.

It should again be noted that the cattle were not being fattened during the winter months; they were simply being carried through so as to be in condition for fattening on grass the following summer. The steers of lots 4 and 5 were confined on cotton fields where cotton had been grown the previous summer. Of course they obtained some feed from these cotton fields, especially during the first part of the winter, and in addition were given a half ration of cottonseed meal, hulls, and hay, as noted below. Lots X and Y were on the open range, with no additional feed. The amount of feed given is shown in the following table:

TABLE 8.—*The average daily amount of feed given each steer during the winter months.*

THE YOUNG STEERS.

[Dec. 6, 1909, to Mar. 31, 1910, 116 days.]

Lot.	Number of steers.	Ration.	Average daily amount.
			Pounds.
4	18	Cottonseed meal	2.35
		Cottonseed hulls	13.29
5	17	Cottonseed meal	2.35
		Cottonseed hulls	6.82
		Johnson-grass hay	5.50

THE COMMON STEERS.

[Dec. 6, 1909, to Apr. 23, 1910, 139 days.]

X Y	43	Open range only	None.

It is seen that none of the steers was fed more than a half ration of purchased feeds. Each steer in lot 4 received an average daily feed of 2.35 pounds of cottonseed meal plus 13.29 pounds of hulls. Each steer in lot 5 consumed an average of 2.35 pounds of cottonseed meal, 6.82 pounds of cottonseed hulls, and 5.5 pounds of Johnson-grass hay daily. These were small amounts of feed, but, as will be seen later, the animals made a fairly good daily gain. During the whole winter each animal in lot 4 ate 273 pounds of cottonseed meal and 1,542 pounds of hulls at a total cost of $8.95. During the same length of time each steer in lot 5 ate 273 pounds of cottonseed meal, 791 pounds of hulls, and 638 pounds of hay, at a cost of $9.83.

The steers in lots X and Y received no feed at all in addition to the cut-over pine range.

WEIGHTS AND GAINS DURING WINTER MONTHS.

The following table shows that all of the cattle gained during the winter months, even the ones which were turned out on the open range and received no feed or attention during the whole winter. In this connection it should be called to mind that these cattle which were turned out on the range were mature animals. They were better able than young animals to care for themselves, as they were strong enough to get about over large areas and hunt for a living. These mature steers can withstand careless treatment and yet come through to spring in fairly good condition, while young animals, like those in lots 4 and 5 might starve with similar feed and treatment. No one would advise a farmer to turn young animals on an open range during the winter months and give them no feed or attention. A young beef animal, if he is to attain a respectable size, must be fed and cared for during the cold months.

TABLE 9.—*Weights and gains during the winter months.*

THE YOUNG STEERS.

[Dec. 6, 1909, to Mar. 31, 1910, 116 days.]

Lot.	Number of steers.	Ration.	Average initial weight of each steer (Dec. 6, 1909).	Average spring weight of each steer (Apr. 1, 1910).	Average total gain of each steer.	Average daily gain of each steer.
			Pounds.	*Pounds.*	*Pounds.*	*Pounds.*
4	18	Cottonseed meal and cottonseed hulls (one-half ration)	624	698	74	0.64
5	17	Cottonseed meal, cottonseed hulls, Johnson-grass hay (one-half ration).	608	676	68	.59

THE COMMON STEERS.

[Dec. 6, 1909, to Apr. 23, 1910, 139 days.]

X Y	43	Range alone	565	[1] 575	10	.08

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[1] Apr. 23, 1910.

The steers in lots 4 and 5 made as good gains as was desired. No effort was made to fatten them. During the whole feeding period of 116 days each steer in lots 4 and 5 gained an average of 74 and 68 pounds, respectively. They were in excellent condition when spring came.

Each steer in the range lots (lots X and Y combined) gained an average of 10 pounds during the whole winter. They, too, were in good condition when grass came in the spring. When cattle are turned onto the open range during the winter, as a rule, they lose instead of gain in weight. In some former work the cattle which had no feed during the cold months except what they secured from the open range, lost approximately 100 pounds each during the winter time,[1] but some allowance should be made for the fact that they came off the range several weeks earlier than lots X and Y. It is, however, a very unusual occurrence for steers to make gain during the winter months when handled and fed as were those in lots X and Y.

QUANTITY AND COST OF FEED REQUIRED TO MAKE 100 POUNDS GAIN DURING THE WINTER.

The following table shows that the gains made during the winter months by the steers in lots 4 and 5 were expensive ones. There is no way to determine the cost of gains made by the range cattle (lots X and Y) as no value or rental price has ever been placed upon the open range.

Table 10.—*Quantity and cost of feed required to make 100 pounds of gain during the winter months.*

THE YOUNG STEERS.

[Dec. 6, 1909, to Mar. 31, 1910, 116 days.]

Lot.	Ration.	Feed required to make 100 pounds of gain.	Cost of feed to make 100 pounds of gain.
		Pounds.	
4	Cottonseed meal	368	$12.05
	Cottonseed hulls	2,077	
5	Cottonseed meal	424	14.71
	Cottonseed hulls	1,160	
	Johnson-grass hay	935	

THE COMMON STEERS.

[Dec. 6, 1909, to Apr. 23, 1910, 139 days.]

Lot.	Ration.	Feed required to make 100 pounds of gain.	Cost of feed to make 100 pounds of gain.
X Y	Range alone	....	Nothing.

Each 100 pounds of gain during the winter months cost $12.05 and $14.71 in lots 4 and 5, respectively. These were very expensive gains and hard to overcome, even when the steers were continued on a very cheap ration—pasture and cottonseed cake—the following summer. In fact, the expensive winter gains of lots 4 and 5 were never counteracted by the cheap gains of the following summer, as money was finally lost on these two lots of cattle. The gains secured during the winter months were expensive by reason of the fact that the ration was too near a mere maintenance ration. It is seen that in lot 4 368 pounds of cottonseed meal plus 2,077 pounds of hulls were required to make 100 pounds of increase in live weight. In lot 5, where Johnson-grass hay was introduced, 424 pounds of cottonseed meal, 1,160 pounds of hulls, and 935 pounds of hay were required to make 100 pounds of gain.

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[1] Bureau of Animal Industry Bulletin 131.

Johnson-grass hay did not improve the ration of cottonseed meal and hulls. Nothing was gained by the introduction of the hay. In comparing the results of lots 4 and 5 it is learned that 935 pounds of Johnson-grass hay saved 917 pounds of hulls, but caused a loss of 56 pounds of cottonseed meal; or, 1 ton of the hay was worth $5.26 in this feeding test, when cottonseed meal and cottonseed hulls are valued at $26 and $7 a ton, respectively. It will be remembered that in Part I of this bulletin the same hay was worth only $1.31 a ton as a fattening feed. (See p. 17.) The nearer a feed or a combination of feeds approaches a mere maintenance ration the more valuable such a hay as Johnson grass becomes.

The small increase in live weight of the steers in lots X and Y was made without cost, as the range, their only feed, was free.

THE SPRING COST OF THE STEERS.

The steers in lots 4 and 5 cost 3½ cents a pound in the fall of 1909; those in lot 4 averaged $21.84 each and those in lot 5 $21.28. They were well-bred animals; no scrubs were among them. The steers in lots X and Y were of a very common grade and cost only 2¼ cents a pound. Although these cattle were not to be fattened for the market until the next summer, they were all bought during the fall of 1909, as it is practically impossible to get together a bunch of cattle in the spring. However, it costs something to feed cattle through the winter months, and the farmer who buys them in the fall with the intention of carrying them until the following summer to fatten for the market is interested in knowing what it will cost to get them through the winter months. In other words, he desires to know the spring cost, which is equal to the fall price plus the cost of getting the cattle through the winter months. If it were possible to get them through the winter months without cost, or without gain or loss in weight, the spring and fall prices would be identical, but this can seldom be accomplished. As a rule, the steers must be fed, and they commonly gain or lose in weight. These expenses and changes in live weight all have a bearing on the spring price.

The following table presents the fall price, the cost to get each steer through the winter, and the spring price after the winter expenses and changes in live weight have been taken into consideration:

TABLE 11.—*Average fall and spring prices of the cattle and cost of winter feeding.*

THE YOUNG STEERS.

[Dec. 6, 1909, to Mar. 31, 1910, 116 days.]

Lot.	Ration.	Fall price per hundredweight.	Cost to feed each steer through the winter.	Spring price per hundredweight.
4	Cottonseed meal Cottonseed hulls	$3.50	$8.95	$4.41
5	Cottonseed meal Cottonseed hulls Johnson-grass hay	3.50	9.83	4.60

THE COMMON CATTLE.

[Dec. 6, 1909, to Apr. 23, 1910. 139 days.]

X Y	Range alone	$2.25	Nothing	$2.21

In lot 4 it cost $8.95 to feed each steer through the winter months. In lot 5, where Johnson-grass hay was used, the expense to feed each steer for the same length of time was raised to $9.83. The Johnson-grass hay increased the expense. When these winter expenses are added to the original cost, and allowance made for the winter gains, the steers in the spring cost $4.41 and $4.60 per hundredweight in lots 4 and 5, respectively, which brought their average price to $30.79 for lot 4 and $31.11 for lot 5.

The steers in lots X and Y were cheaper at the end of the winter than they were the previous fall. This was due to the fact that they gained a few pounds during the winter months (10 pounds each), when no expense was attached to feeding them, as they were grazed on the open range. It is, of course, an unusual occurrence for these two factors to be combined in this way. These cattle were bought in the fall of 1909 for $2.25 a hundredweight, but when spring arrived, April 23, 1910, their cost per hundredweight was reduced to $2.21.

FATTENING THE CATTLE ON PASTURE.

At the close of the winter tests the steers were redivided into lots, turned into the summer pastures, and fattened for the late summer market.

The winter feeding in lots 4 and 5 was discontinued March 31, 1910. On April 2, 1910, the pastures were ready for grazing, so the summer fattening tests were inaugurated on this date. The steers in lots 4 and 5 were combined into one lot and grazed upon the same pasture throughout the summer experiment.

The range or common cattle (lots X and Y) were divided into two lots, as nearly equal as possible in quality, size, and breeding, and placed upon separate pastures on April 23, 1910. Lot X was fed cottonseed cake along with the pasture; lot Y was fed nothing except pasture.

The feeding was done once a day in open feed troughs; these troughs were conveniently located in the pastures. In order that all of the cattle would come out to the troughs the feeding was done in the cool of the evening or about sundown.

An abundance of water and salt was kept before the animals all the time.

DAILY RATIONS.

To avoid scouring and other ill results, steers which are being fattened must become accustomed gradually to cottonseed meal and cottonseed cake. Many feeders increase the feed too rapidly for best results. The temptation is to get the steers on full feed within a few days after the feeding begins, but this tendency should be curbed. The following table illustrates the amount of cottonseed cake given each steer daily by periods of 28 days:

TABLE 12.—*Daily ration for each steer during summer fattening.*

Period.	Cottonseed cake and pasture.	
	Young steers, lots 4 and 5 combined (Apr. 2 to Aug. 26, 1910, 147 days).	Common steers, lots X and Y[1] (Apr. 23 to Sept. 2, 1910, 133 days).
	Pounds.	*Pounds.*
First 28 days	2.19	2.84
Second 28 days	4.36	3.48
Third 28 days	5.50	3.48
Fourth 28 days	6.00	5.00
Fifth 28 days	6.00	[2] 4.91
Last 7 days	5.14	....

[1] Pasture only.

[2] Last 21 days.

Attention is again called to the fact that the results secured in lots 4 and 5 (now combined into one lot) can not be compared with those secured in lots X and Y. It should be noted that these lots were not started on feeds at the same date, sold at the same time, or fed and cared for similarly the preceding winter. This is not a test in which common cattle are compared with good ones. Lots X and Y, however, are comparable with each other.

All of the cattle, except lot Y, which were on pasture alone, were given a very small daily feed of cake during the first few weeks. Each of the young steers received an average of only 2.19 pounds of cake daily during the first 28 days. This amount was increased from time to time, as shown in the table. For a time each steer was eating 6 pounds of cake a day, but this amount was finally reduced somewhat on account of scouring and hot weather.

At first the common steers (lot X) were also given a very small allowance of cottonseed cake, each steer receiving an average of 2.84 pounds of cake daily during the first 28 days. The steers in this lot were never given a daily feed of over 5 pounds of cake. The steers in lot Y received no feed at all in addition to the pasture, the object being to learn whether it would pay to feed cottonseed cake to steers of this grade while grazing a fairly good pasture.

WEIGHTS AND GAINS ON PASTURE.

The following table shows the average initial weight, average final weight, and the total gains and average daily gains of each steer. All of the gains were unsatisfactory. To have been entirely satisfactory the average daily gains should have been not less than 2 pounds. The authors are unable to state positively why the gains were no greater, but it was probably due to the unusual amount of rain during the grazing season. The pastures were on low grounds which continued extremely wet throughout the greater part of the test. The grass made a good growth and the steers seemed to be well filled practically all of the time, but of course the grass that they obtained was very soft and full of water.

TABLE 13.—*Weights, total gains, and average daily gains of the steers during the summer of 1910.*

THE YOUNG STEERS.

[Apr. 2 to Aug. 26, 1910, 147 days.]

Lot.	Number of steers,	Ration.	Average initial weight of each steer.	Average final weight of each steer.	Average total gain of each steer.	Average daily gain of each steer.
			Pounds.	*Pounds.*	*Pounds.*	*Pounds.*
4 5	35	Pasture and cottonseed cake	687	855	168	1.14

THE COMMON STEERS.

[Apr. 23 to Sept. 2, 1910, 133 days.]

X	28	Pasture and cottonseed cake	572	761	189	1.42
Y	15	Pasture alone	580	757	177	1.33

Each of the young steers made a total gain of 168 pounds during the 147 days that they were on feed. This was an average daily gain of 1.14 pounds. As stated before, these gains were exceedingly unsatisfactory. With the amount of cottonseed cake they received along with the pasture it was expected that they would make not less than an average daily gain of 2 pounds a day. In some former feeding work[1] the daily gains secured averaged more than 2 pounds when the pastures were supplemented by cottonseed cake.

The common cattle of lot Y (pasture alone) made fairly satisfactory gains, although larger gains were expected. Each steer made an average daily gain of 1.33 pounds, or a total gain of 177 pounds for the whole summer of 133 days. The steers (lot X) which received some cottonseed cake along with the pasture made a very little larger daily gain than the ones on pasture alone. Each cake-fed steer made an average daily gain of 1.43 pounds, or a total gain of 189 pounds for the whole summer, while the pasture steers each gained 177 pounds, or an average daily gain of 1.33 pounds.

QUANTITY AND COST OF FEED REQUIRED TO MAKE 100 POUNDS GAIN.

When cattle are being fattened and the gains are small, they are almost certain to be expensive. The results secured in this experiment were no exception to the general rule. The table following shows that the summer gains were extremely expensive when compared with former experiments that have been made in this State. At least two factors were involved in making these summer gains expensive. First, the cattle were fed a rather heavy ration of high-priced cottonseed cake along with the pasture, and, second, the cattle did not respond to the liberal feeding, due probably at least in part to the wet pastures.

TABLE 14.—*Quantity and cost of feed required to make 100 pounds of gain.*

THE YOUNG STEERS.

[Apr. 2 to Aug. 16, 1910, 147 days.]

Lot.	Number of cattle.	Ration.	Total cost of feed and pasture for each steer.	Feed required to make 100 pounds of gain.	Cost to make 100 pounds of gain (including pasture).
4 5	35	Pasture and cottonseed cake	$11.54	*Pounds.* 423	$7.06

THE COMMON CATTLE.

[Apr. 23 to Sept. 2, 1910, 133 days.]

Lot.	Number of cattle.	Ration.	Total cost of feed and pasture for each steer.	Feed required to make 100 pounds of gain.	Cost to make 100 pounds of gain (including pasture).
X	28	Pasture and cottonseed cake	$9.10	274	$4.82
Y	15	Pasture alone	2.38	None.	1.55

It cost $11.54 to feed each steer in lots 4 and 5 through the summer when cottonseed cake is valued at $26 a ton and the pasture at 50 cents a month for each animal. Or it required 423 pounds of cottonseed cake, at a cost of $7.06, to make 100 pounds of increase in live weight. This was an unusually expensive gain for summer feeding.

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[1] See Bureau of Animal Industry Bulletin 131, p. 40.

The following extract is taken from Bureau of Animal Industry Bulletin 131, page 41, which is a report of some previous work done in fattening cattle in the summer time on pasture:

> In every case above the cost to make 100 pounds increase in live weight was very low. (In one case $1.18 when pasture was used alone, in another case $1.03; when cottonseed cake was used it cost only $2.56 to make 100 pounds of gain in one experiment, and $3.21 in a second test.) When steers are fattened during the winter time each pound of gain is put on at a loss, as each pound put on may be expected to cost from 8 to 12 cents; and the profit is dependent upon the enhancement of the value of the steer over and above the selling value of pounds of gain made. In these tests each pound put on during the fattening period was put on at a profit, a very unusual occurrence in fattening beef cattle. These cheap finishing gains made the feeding operations comparatively safe as far as profits were concerned. As stated before, these cheap gains were due to two factors; first, the cattle had a cheap and succulent roughage—pasture. Second, the amount of concentrated feeds used was kept down to a comparatively small figure; from 2.76 to 3.31 pounds of cottonseed cake and 4.48 pounds of cotton seed were fed each steer daily.

In lot X, one of the lots of common cattle, 274 pounds of cake were required to make 100 pounds of gain, at an expense of $4.82 per hundredweight. To feed each steer in this lot all summer it cost $9.10, when the feeds are valued as above. The cattle in lot Y received no cake in addition to the pasture, so it cost only $2.38 to feed each one from April 23 to September 2, when pasture is valued at 50 cents a month per head.

FINANCIAL STATEMENT OF THE SUMMER FEEDING.

As stated before, the cattle in lots 4 and 5 cost 3½ cents a pound in the fall of 1909. These cattle were fed through the winter of 1909–10 on a light ration of feeds as heretofore outlined. When spring arrived, and the expense of the winter feeding had been added to fall price, the steers had cost $4.41 and $4.60 per hundredweight respectively. These were the values placed upon them at the beginning of the summer feeding, April 2, 1910. On August 26, 1910, they were sold for $4.50 per hundredweight on the farm, after a 3 per cent shrink.

The common cattle in lots X and Y were also purchased in the fall of 1909, costing, however, only 2¼ cents a pound. They ate no expensive feeds during the winter months as they were turned out on the open range. On April 23, 1910, they were taken off this winter range and weighed again, and it was learned that each steer had gained 10 pounds during the winter. Owing to the fact that they had been fed no feeds during the winter upon which a price was placed (open range has no value placed upon it), they were really cheaper in the spring of 1910 than they were the previous fall, as they had gained in weight. This condition of affairs is, of course, very unusual. When this increase in weight was taken into consideration, the cattle cost $2.21 per hundredweight in the spring of 1910; at the beginning of the summer work this value was placed upon them. On September 2, 1910, they were sold and shipped to the Atlanta market, realizing $3.87½ per hundredweight for lot X, and $3.60 per hundredweight for lot Y.

Financial statement of lots 4 and 5.

Lot 4. Cottonseed cake and pasture:		
By sale 18 steers, 15,064 pounds, at $4.50 per hundredweight		$677.88
To 18 steers, 12,566 pounds, at $4.41 per hundredweight	$554.16	
To 12,770 pounds cottonseed cake, at $26 per ton	166.01	
To pasture for 5¼ months, at 50 cents a month per head	47.25	
Total expense		767.42
Total loss		89.54
Loss per steer		4.97
Lot 5. Cottonseed cake and pasture:		
By sale 17 steers, 13,978 pounds, at $4.50 per hundredweight		629.01
To 17 steers, 11,494 pounds, at $4.60 per hundredweight	$528.72	
To 12,061 pounds cottonseed cake, at $26 a ton	156.79	
To pasture for 5¼ months, at 50 cents a month per head	44.62	
		730.13
Total loss		101.12
Loss per steer		5.95

It is seen that the steers in both of these lots were fed at a loss, each steer losing $4.97 and $5.95 in lots 4 and 5, respectively. It should be noted that the expense of feeding these cattle through the previous winter is also charged against them in the above statements. The steers in lot 4 were fed through the previous winter on cottonseed meal and hulls, while those of lot 5 had some Johnson-grass hay added to the basal ration of cottonseed meal and hulls. More money was lost on the steers in lot 5 because of the fact that Johnson-grass hay increased the expense of the winter ration. (See p. 16.)

This work clearly shows that profits can not be made upon cattle when the conditions are as they were in this test. It is true that the beef cattle market was demoralized just at the time of sale, but even with a normal market it would have been impossible to have made money on these young steers. To have come out even on the operation the steers of lots 4 and 5 would have had to sell for $5.09 and $5.24 per hundredweight, respectively. This they would not have done even under normal market conditions. Too much high-priced feed had been fed to these steers. Furthermore, subsequent work seems to teach that, while they were fed too long a time in the summer, they were not fed liberally enough during the winter. If they had been sold earlier in the summer the financial outcome would not have been so discouraging, as the price would have been better and considerable high-priced feed would have been saved. In fact, a little profit would have been secured if they had been sold about July 1. Then again, the expense of feeding them during the winter was heavy, while only small gains were secured. It cost $8.95 and $9.83 to feed each steer in lots 4 and 5 through the winter months. If profits are to be made in handling cattle in this manner, the winter feed bill must be carefully looked after.

Two or three methods of feeding can be adopted by which the winter feeding can be done more economically than was the case in these tests. In the first place, these young steers were not fed a sufficient amount of feed during the winter months. Their ration was too nearly a mere maintenance ration. In the second place, the open range in some parts of the State can be used to supplement the high-priced feeds. With young animals the range can never entirely take the place of high-priced feeds, as young animals must be fed during the winter months if satisfactory results are secured. This system of wintering cattle, however, will disappear as soon as the State becomes more densely populated and the large farms are divided into small ones. In the third place, the old cotton and corn fields can be made to be exceedingly profitable when fenced; both the young and old animals can be turned on these fields and oftentimes secure one-half of their winter feed from them. This third method is a permanent one and will be introduced more and more as our farming conditions change.

Financial statement of lots X and Y.

Lot X. Cottonseed cake and pasture:		
By sale 28 steers, 20,665 pounds, at $3.87½ per hundredweight		$800.77
To 28 steers, 16,011 pounds, at $2.19 per hundredweight	$350.64	
To 14,493 pounds cottonseed cake, at $26 a ton	188.41	
To pasture, 4¾ months, at 50 cents a month per head	66.50	
		605.55
Total profit		195.22
Profit per steer		6.97
Lot Y. Pasture alone:		
By sale 15 steers, 11,008 pounds, at $3.60 per hundredweight		396.29
To 15 steers, 8,697 pounds, at $2.25 per hundredweight	$195.68	
To pasture, 4¾ months, at 50 cents a month per head	35.63	
		231.31
Total profit		164.98
Profit per steer		11.00

It may be noted that the spring price of these cattle is stated in other places to be $2.21 per hundredweight. This is correct for the entire lot, but after they were divided it was found that the value of lot X was $2.19 and lot Y $2.25 per hundredweight.

These steers were sold on the farm with a 3 per cent shrink. Those in lot X sold for $3.87½ per hundredweight and those in lot Y for

$3.60. Exceedingly satisfactory profits were made on these cattle, $6.97 clear profit being made on each steer in lot X, while each animal in lot Y returned a profit of $11.

In this particular experiment it did not pay to supplement the pasture with the cottonseed cake; more money would have been made if the cake had not been used. These results, however, do not agree with others secured in former work.[1] The cattle in lot X did not respond to the extra feed of cottonseed cake; this is shown to be true by the daily gains. The steers in lot Y, where no cake was fed, made an average daily gain of 1.33 pounds, while the steers of lot X, where the cake was fed along with the pasture, made an average daily gain of only 1.42 pounds. This is unusual and the authors regard the results as abnormal.

SLAUGHTER RECORDS.

The steers of lots 4 and 5 were shipped to Atlanta, where complete slaughter records were secured. Those of lots X and Y were also shipped to Atlanta, but no slaughter data were secured.

TABLE 16.—*Shipping weights and slaughter data.*

Lot.	Number of steers.	Total weight on farm.	Total weight at Atlanta.	Shrinkage en route per steer.	Total dressed weight at Atlanta.	Per cent dressed out by farm weight.	Per cent dressed out by Atlanta weight.
		Pounds.	*Pounds.*	*Pounds.*	*Pounds.*		
4	18	15,530	14,920	33.9	8,252	53.1	55.3
5	17	14,402	13,740	38.9	7,531	52.3	54.8

The cattle were driven 4 miles from the farm to the railroad. The shrinkage en route was comparatively small, being 33.9 pounds and 38.9 pounds for each animal in lots 4 and 5, respectively. By Atlanta weights the steers in lot 4 dressed 55.3 per cent, while those in lot 5 dressed 54.8 per cent.

SUMMARY.

1. Two separate tests are reported in Part II. The steers in lots 4 and 5 were a high-grade bunch of young cattle; those in lots X and Y were the common cattle of Sumter and neighboring counties. These tests are not comparable.

2. The steers in lots 4 and 5 were carried through the winter of 1909–10 on the following feeds:

Lot 4: Cottonseed meal, cottonseed hulls. Lot 5: Cottonseed meal, cottonseed hulls, Johnson-grass hay.

The general plan was to give sufficient feed to produce small gains throughout the winter months. No effort was made to fatten the steers, as they were to be fattened the following summer on pasture.

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[1] See Bureau of Animal Industry Bulletin 131.

3. The steers in lots X and Y were carried through the winter of 1909–10 on the range alone; no purchased feeds were used. The object was to fatten these cattle the following summer on pasture.

4. The steers in lots 4 and 5 ate the following amounts of feed each day during the winter:

Lot 4: Cottonseed meal, 2.35 pounds; cottonseed hulls, 13.29 pounds. Lot 5: Cottonseed meal, 2.35 pounds; cottonseed hulls, 6.82 pounds; Johnson-grass hay, 5.50 pounds.

5. The test was inaugurated December 6, 1909. On this date the steers in lots 4 and 5 averaged 624 and 608 pounds in weight. At the close of the winter period. April 1, 1910, the steers had attained an average weight of 698 and 676 pounds in the respective lots.

6. The steers in lots X and Y (combined during the winter months) averaged 565 pounds in weight at the beginning of the test, December 6, 1909. At the close of the winter, April 23, 1910, they had attained an average weight of 575 pounds.

7. To feed each steer through the winter cost $8.95 and $9.83 in lots 4 and 5, respectively. Johnson-grass hay increased the expense; it did not pay to use the hay along with the cottonseed meal and hulls.

8. The steers in lots 4 and 5 cost 3½ cents a pound when they were purchased in the fall of 1909. At the end of the winter feeding they had cost $4.41 and $4.60 per hundredweight, respectively, after the gains were taken into consideration.

9. Owing to the fact that the common cattle in lots X and Y were fed nothing except range during the cold months, but at the same time gained a little in weight, they were cheaper when spring opened than they were the previous fall. They were bought in the fall of 1909 for $2.25 per hundredweight, and at the end of the winter period, April 23, 1910, their cost per hundredweight was reduced to $2.21.

10. When the spring of 1910 arrived all the cattle were turned on pasture and fattened for the late summer market. Lots 4 and 5 were combined into one lot, while lots X and Y were separated into two lots. The steers in lots 4 and 5 were fed cottonseed cake along with pasture from April 2, 1910, to August 26, 1910. The steers in lots X and Y were given the following feeds from April 23, 1910, to September 2, 1910: Lot X, pasture and cottonseed cake; lot Y, pasture alone.

11. The steers in lots 4 and 5 (now combined) made an average daily gain of only 1.14 pounds during the pasture season. This was unsatisfactory.

12. The steers in lots X and Y made an average daily gain of 1.42 and 1.33 pounds, respectively, during the pasture season. This was also unsatisfactory.

13. Including the cost of pasture, it cost $7.06 to make 100 pounds of gain in lots 4 and 5 during the pasture period. These were unusually expensive gains for the summer season.

14. Including the cost of pasture, it cost $4.82 and $1.55 to make 100 pounds of gain in lots X and Y, respectively.

15. The reader's attention is called to the fact that the results secured with lots 4 and 5 are not comparable with those secured with lots X and Y.

16. Money was lost on the cattle in lots 4 and 5—$4.97 on each steer in lot 4, and $5.95 on each one in lot 5.

17. Excellent profits were realized on the cattle in lots X and Y—$6.97 on each steer in lot X, and $11 on each one in lot Y.

In this experiment it did not pay to supplement the pasture with the cottonseed cake. This result, however, does not agree with other results secured in former experiments. For reasons stated in the text of this bulletin, the authors regard the results as abnormal.

III. THE VALUE OF SHELTER FOR FATTENING CATTLE IN ALABAMA.

INTRODUCTION.

During the winters of 1904, 1905, and 1906 this bureau, working in cooperation with the Alabama Experiment Station, carried through some tests to determine the value, if any, of shelter in fattening southern steers. These results were published in Bulletin 103 of the Bureau of Animal Industry. In comparing the daily gains the authors stated:

> The animals in pen 2 were fed under an open shed, and pen 6 had no shelter. The average daily gains for the three years was 1.55 pounds for the pen under shelter and 1.47 pounds for the lot without shelter. In the two wet winters (1904–1905 and 1905–1906) the largest daily gains were made by the lot under shelter; but in the mild and rather dry weather of 1906–1907 the lot without shelter made more rapid gains.

With regard to feed requirements the authors further stated:

> In two experiments out of three and in the average for three years, shelter resulted in a slight economy in use of concentrated feeds and a slight loss in the use of roughage. In other words, shelter, on the whole, saved 0.2 of a pound of cottonseed meal per pound gain and lost 0.49 of a pound of roughage. The steers out of doors consumed a larger ration of roughage.

Or, in other words, when the cottonseed meal is valued at $26 a ton and hulls at $7 a ton the shelter saved practically 9 cents on every 100 pounds of gain made. Sheds can not be built and maintained with this small saving.

However, the above steers were not managed, with reference to bedding and available space for exercise, as they are usually fed on the farms of Alabama.

> The feed lots were 16 by 90 feet, the ground sloping away from the shed. These lots had a good slope, but still became very muddy in wet weather. The lot without shelter was at times several inches deep in mud, so that the steers had no dry place to lie down. None of the lots were bedded, though the sheds were. The feed troughs were under the sheds. The water troughs were near the feed troughs and under the shed, the water being supplied from a well. The troughs had float valves, so that a fresh supply of water was kept in them at all times.

The average feeder of the State does not confine the fattening steers in small lots 16 by 90 feet; the Bureau and Station authorities, however, on account of the lack of ground, had to do so, and of course the steers in the lot without shelter were at a disadvantage on account of the deep mud. When the farmer feeds without shelter the steers can usually find a dry piece of ground on which to lie, as they are not confined in small lots.

In connection with another line of work during the winter of 1910–11 an opportunity presented itself to carry through another experiment along this line upon an extensive scale, and the conditions surrounding the present test were more nearly in keeping with average farm conditions than were those of the former experiments.

The work was done in cooperation with Mr. E. F. Allison, of Sumter County, Ala. Mr. Allison furnished the cattle and the feed, and the Bureau of Animal Industry and the Alabama Experiment Station provided a trained man to look after the details of feeding. Mr. L. W. Shook was stationed on the farm and had personal supervision of the experiment.

PLAN OF THE EXPERIMENT.

This work was planned with two objects in view:

1. To study various methods of making and saving manure when beef cattle are fattened during the winter months.

One lot of steers was fed on a 5-acre tract of level sandy land, so that all the manure they made was deposited upon the land without the expense of hauling. A second bunch of cattle was fed in a small lot, across one side of which was a good shed. Both the lot and the shed were bedded when necessary. The steers could always find dry places upon which to lie. An accurate account was kept of the amount of bedding hauled; the labor required to haul it, and the expense of hauling the manure from the barn to a second 5-acre tract of land adjoining the first tract. The comparative value of the two methods of making and saving manure is to be finally measured in terms of subsequent yields of corn and cotton.

2. To study the value, if any, of shelter in fattening southern beef animals.

The results of the second object are reported in the following pages. Sufficient information relative to the first object has not been collected to warrant a report.

THE CATTLE.

The cattle used in this test were a mixed lot of steers, heifers, and cows, averaging from 2 to 4 years of age. As the main object of the test was to study methods of making and saving manure, the quality of the animals was somewhat neglected. They were the common cattle of Sumter and neighboring counties; only a very few showed signs of improved beef blood. They cost $2.30 per hundredweight during the late fall of 1910. The price paid shows that the quality was poor, as the best feeders of the county were selling for $3 to $3.50 per hundredweight.

PRELIMINARY MANAGEMENT AND FEEDING.

A few of the cattle were raised upon the farm where the experiment was conducted; the majority, however, were purchased from neighbors. Some of the cattle were purchased early in the fall; these, together with the few that were raised on the farm, were grazed upon a large pasture, with no additional feed, from October 10 to October 21, 1910. On October 21, 30 head were taken from this pasture and turned into a peanut pasture where hogs and sheep were grazing. While they were on peanuts each animal was given a daily feed of 1 pound of cottonseed cake. On October 31 they were taken back to the first-mentioned pasture and the daily allowance of cake was raised to 2 pounds for each animal. As cold weather approached the value of the pasture gradually decreased, and the amount of cake was therefore gradually increased. By December 16, 1910, each animal was eating practically 4 pounds of cake each day. On this date they were taken off the pasture, as it was of no further value, and the test inaugurated.

The cattle were all dehorned before the experiment began.

Individual weights of the cattle were secured at the beginning and end of the test. Lot weights were secured every 28 days.

Feeding was done twice each day, once about 7 o'clock in the morning and again at 4 o'clock in the afternoon. The cottonseed meal was mixed with the hulls by hand. Water was kept before the cattle all the time. Salt was fed once a week.

LOTS AND SHELTER.

The cattle were divided into two lots. Lot 1 was fed in a small lot, across the east side of which extended a shed and the feed troughs; the animals therefore had the privilege of standing either under the shed or in the open lot. From time to time sufficient bedding was hauled to cover the entire lot. The object was to keep the whole lot well bedded, but several times during the test that part of the lot not under shelter became exceedingly muddy. However, the cattle could always find dry places.

The steers in lot 2 were fed on a 5-acre tract of sandy land with no shelter at all. This tract of land had been under cultivation for several years, so the trees had been removed. The feed troughs, which were also in the open, were made in such a way that they could be pulled from place to place; in this way the manure was evenly distributed over the field. The soil was sandy, so the ground never became exceedingly muddy, although the winter of 1910–11 was an unusually wet one.

CHARACTER AND PRICE OF FEEDS.

Cottonseed meal and cottonseed hulls were fed to both lots. No other feeds were used. Both the meal and hulls were of good quality. The following prices were taken as a basis upon which to make the financial estimates:

	Per ton.
Cottonseed meal	$26.00
Cottonseed hulls	7.00

DAILY RATIONS.

There seems to be no doubt that the majority of our southern farmers feed too much cottonseed meal to cattle which are being fattened. The average feeder is tempted to increase the amount of cottonseed meal too rapidly at the beginning of the feeding period and continue to increase the amount until the total feed of meal is entirely too great. When this is done the cattle are oftentimes "burnt out" by the time they have been fed from 70 to 80 days and must then be sold often under unfavorable market conditions. "Burnt out" cattle can not be held for better market conditions.

The table below shows the average daily ration of cottonseed meal and hulls in this experiment by periods of 28 days each:

TABLE 17.—*Average quantity of feed eaten by each animal daily.*

[Dec. 16, 1910, to Mar. 28, 1911, 103 days.]

Period.	Lot 1 (shelter).	Lot 2 (no shelter).
First 28 days	4.15 pounds cottonseed meal 18.11 pounds cottonseed hulls	4.19 pounds cottonseed meal. 16.63 pounds cottonseed hulls.
Second 28 days	5.04 pounds cottonseed meal 20.17 pounds cottonseed hulls	5.05 pounds cottonseed meal. 20.12 pounds cottonseed hulls.
Third 28 days	5.33 pounds cottonseed meal 19.39 pounds cottonseed hulls	5.20 pounds cottonseed meal. 19.51 pounds cottonseed hulls.
Last 19 days	5.19 pounds cottonseed meal 18.61 pounds cottonseed hulls	5.18 pounds cottonseed meal. 18.69 pounds cottonseed hulls.

At the beginning of the test the cattle averaged 578 and 585 pounds in weight in lots 1 and 2, respectively.

These cattle were, in a way, accustomed to cottonseed meal, as they had received a small feed of cottonseed cake for several weeks previous to the beginning of the experiment, yet their daily allowance of meal was below 3 pounds an animal for several days after the test begun. This amount was gradually raised and each steer ate an average of 4.15 pounds of cottonseed meal daily during the first 28 days; along with this amount of meal an average of 18.11 pounds of hulls were consumed daily by each animal. They were given all of the hulls they would clean up. The cattle in lot 2 ate practically the same as those in lot 1. The heaviest feeding of cottonseed meal occurred in lot 1 during the third period, when an average of 5.33 pounds of cottonseed meal was given each animal daily.

The feeding continued for 103 days, yet no ill results, such as dizziness, staggering, or blindness, followed the use of the cottonseed meal. As before stated, many feeders, on account of the excessive use of cottonseed meal, are not able to feed for more than 80 days.

WEIGHTS AND GAINS.

Although the daily allowance of cottonseed meal was maintained at a rather small amount, the cattle made satisfactory gains. At the same time no losses were sustained as a result of feeding meal too liberally.

TABLE 18.—*Weights and gains.*

[Dec. 16, 1910, to Mar. 28, 1911.]

Lot.	Number of cattle.	Ration.	Initial weight Dec. 16, 1910.	Final weight Mar. 26, 1911.	Total gain of each animal.	Average daily gain of each animal.
			Pounds.	*Pounds.*	*Pounds.*	*Pounds.*
1 (shelter)	33	Cottonseed meal and cottonseed hulls.	578	754	176	1.71
2 (no shelter)	34	do	585	757	172	1.67

Each animal in lot 1, fed under shelter, weighed on an average 578 pounds at the beginning and 754 pounds at the close of the test, making a total gain of 176 pounds, or an average daily gain of 1.71 pounds. It is seen that the cattle which had no shelter (lot 2) also made good gains, as each one made a total gain of 172 pounds during the test, or an average daily gain of 1.67 pounds. As far as gains were concerned, the shelter was of no practical value, as the cattle with shelter made an average total gain of only 4 pounds more than the ones without shelter.

QUANTITY AND COST OF FEED REQUIRED TO MAKE 100 POUNDS GAIN.

Many feeders believe that a fattening animal will increase in weight during the winter months very much more economically when he is sheltered than when he is forced to remain out in the open weather. The following table shows that there are, at least, no striking results to be secured from the employment of shelter for fattening animals under the conditions of this test:

TABLE 19.—*Quantity and cost of feed required to make 100 pounds of gain.*

[Dec. 16, 1910, to Mar. 28, 1911.]

Lot.	Ration.	Feed required to make 100 pounds of gain.	Cost to make 100 pounds of gain.
		Pounds.	
1 (shelter)	Cottonseed meal	288	$7.66
	Cottonseed hulls	1,120	
2 (no shelter)	Cottonseed meal	292	7.72
	Cottonseed hulls	1,122	

When shelter was employed (lot 1) it required 288 pounds of cottonseed meal and 1,120 pounds of hulls, at a cost of $7.66, to make 100 pounds of gain. When no shelter was provided (lot 2) the same gains were made with 292 pounds of meal and 1,122 pounds of hulls, at a cost of $7.72. In other words, the shelter saved 6 cents on each 100 pounds of gain made.

Sheds or barns can not be built and maintained with this small saving. Other considerations, however, may make it profitable to employ a good shelter for fattening cattle. For instance, when it is impossible to save the manure in any other way it is, without doubt, a wise thing to build barns or sheds for conserving it.

PROFITS ON COTTONSEED MEAL AND HULLS AS A RESULT OF FEEDING THEM TO THE CATTLE.

In this test the cottonseed meal and hulls were sold by means of the cattle at a handsome profit. Furthermore, the fact must not be overlooked that the greater part of the fertilizer value of these feeds was left on the farm after they had passed through the cattle. The financial statement shows that with lot 1 the total cost of the meal and hulls was $444.17, and there remained a clear profit of $227.15 after paying all expenses. With lot 2 the result was even better, the feed in this case costing $451.81 and the net profit being $254.34.

FINANCIAL STATEMENT.

This mixed bunch of cattle was bought during the fall of 1910 for an average price of $2.30 per hundredweight. When they were ready to be shipped they were driven 3 miles to the railroad at Bellamy, Ala., and sent to New Orleans, where slaughter data and sale prices were secured. It cost 40 cents a hundredweight to ship them to New Orleans, when freight, commission, yardage, weighing, labor, and feed en route were all taken into consideration. At New Orleans the cattle in lot 1 sold for an average price of $5 per hundredweight, while those in lot 2 sold for an average price of $5.06 per hundredweight.

Financial statement.

Lot 1. Shelter:		
By sale of 33 cattle, 24,134 pounds, at $5 per hundredweight		$1,206.70
To 33 cattle, 19,080 pounds, at $2.30 per hundredweight	$438.84	
To 11,677 pounds cottonseed meal, at $26 per ton	216.80	
To 64,962 pounds cottonseed hulls, at $7 per ton	227.37	
To shipping expenses, at 40 cents per hundredweight	96.54	
Total expense		979.55
Total profit		227.15
Profit per animal		6.88

Lot 2. No shelter.

By sale of 34 cattle, 24,963 pounds, at $5.06 per hundredweight		$1,263.13
To 34 cattle, 19,875 pounds, at $2.30 per hundredweight	$457.13	
To 17,084 pounds cottonseed meal, at $26 per ton	222.09	
To 65,634 pounds cottonseed hulls, at $7 per ton	229.72	
To shipping expenses, at 40 cents per hundredweight	99.85	
Total expense		1,008.79
Total profit		254.34
Profit per animal		7.48

Each animal in lot 1 returned a clear profit of $6.88 above all expenses, while each animal in lot 2 returned a profit of $7.48. Therefore the animals which had no shelter were finally more profitable than those which were provided with a good barn. This was due to the fact that the cattle without shelter sold for a little higher price at New Orleans than the others.

SUMMARY.

TABLE 21.—*Summary statement.*

	Lot 1 (shelter).	Lot 2 (no shelter).
Average cost of cattle in fall 1910, per hundredweight.	$2.30	$2.30.
Ration for each lot	Cottonseed meal and cottonseed hulls.	Cottonseed meal and cottonseed hulls.
Average initial weight of each animal.	578 pounds	585 pounds.
Average final weight of each animal	754 pounds	757 pounds.
Average total gain of each animal	176 pounds	172 pounds.
Number of days on feed	Dec. 16, 1910, to Mar. 28, 1911 (103 days).	Dec. 16, 1910, to Mar. 28, 1911 (103 days).
Average daily gain	1.71 pounds	1.67 pounds.
Feed to make 100 pounds of gain	288 pounds meal, 1,120 pounds hulls.	292 pounds meal, 1,122 pounds hulls.
Cost to make 100 pounds gain	$7.66	$7.72.
Selling price of cattle per hundredweight in New Orleans.	$5.00	$5.06.
Entire cost per hundredweight to ship them to New Orleans.	$0.40	$0.40.
Total profit on each animal	$6.88	$7.48.

1. The cattle (67 in number) used in the test were a mixed lot of steers, heifers, and cows, averaging from 2 to 4 years of age. As the original object of the work (not reported, however, in this publication) was to study methods of making and saving manure, the quality of the animals was somewhat neglected.

2. The object of the experiment, herein reported, was to study the value, if any, of shelter in fattening southern beef animals.

3. The cattle cost on the average $2.30 per hundredweight.

4. The test was inaugurated December 16, 1910, and closed March 28, 1911, a period of 103 days.

5. The cattle were divided into 2 lots, one without shelter and one with shelter. Both lots were fed similar rations of cottonseed meal and cottonseed hulls.

6. At the beginning of the test the average weight of each animal in lots 1 and 2 was 578 and 585 pounds, respectively.

7. Each animal in lots 1 and 2 made an average total gain of 176 and 172 pounds, respectively.

8. In lot 1, where shelter was employed, it required 288 pounds of cottonseed meal and 1,120 pounds of hulls to make 100 pounds of gain in live weight, while in lot 2, where no shelter was used, 292 pounds of meal and 1,122 pounds of hulls were required to make the same gains.

9. It cost $7.66 and $7.72 to make 100 pounds of increase in live weight in lots 1 and 2, respectively.

10. Shelter saved only 6 cents on each 100 pounds of gain made.

11. A clear profit of $6.88 and $7.48 was made on each animal in lots 1 and 2, respectively.

IV. EARLY COMPARED WITH LATE FATTENING OF STEERS ON PASTURE.

INTRODUCTION.

The farmer who fattens cattle on pasture is often undecided as to the proper time to sell. The cattle may be sold during the early summer months, after being fed for 90 days, or they may be carried throughout the whole pasture period and sold late in the fall just before the pastures are exhausted. The feeder, however, is familiar with the fact that fat cattle bring better prices in the early than in the late summer months. Few cattle of any kind are offered for sale during May, June, and the early part of July, so that if fat steers are held and not marketed until August and September they come in competition with thousands of grass-fat cattle. This large supply of grass cattle naturally depresses the prices of all classes. However, gains are made cheaply during the pasture season, and notwithstanding the fact that cheaper prices obtain late in the summer, the feeder often can not decide whether it would pay better to rush his animals for the early summer market, or feed a small supplementary feed, thus making the gains cheaply and slowly, and sell late in the summer.

In order to assist the farmer in dealing with this feeding problem, the experimental work hereinafter described was undertaken. When steers are bought right, fed correctly, and sold intelligently, it has been previously demonstrated that satisfactory profits can be realized when they are fattened on pasture.[1] The present test was carried out with the object of studying the problem as to whether it is more profitable to begin feeding early in the spring and feed a rather heavy ration of cottonseed cake along with the pasture for a short time, or to delay the inauguration of the feeding until the pasture grasses are well started in the spring and feed a light ration of cake along with the pasture for a longer period of time.

PLAN OF THE WORK.

The test, extending over three years, was carried on during the pasture seasons of 1909, 1910, and 1911. The cattle in each case were bought the previous fall, because they could be bought much cheaper in the fall than in the spring. In fact, steers in this section can hardly be purchased at all during the spring months. As they were not to be fattened until the following summer, it was necessary to make a study of the cheapest and best methods of getting them through the winter months. However, this part of the test is not presented here. Some results of wintering steers preparatory to summer fattening may be seen in Part II of this bulletin, and in Bureau of Animal Industry Bulletin 131.

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[1] See Bureau of Animal Industry Bulletin 131.

When the grass appeared in the spring the winter feeding was discontinued, and the pasture fattening work inaugurated. The feeding was done on the farm of Messrs. Cobb and McMillan, of Sumter County, Ala. They purchased the cattle and the feed, and provided the pastures, which were divided into various fields in order to facilitate the work. The bureau and the Alabama Experiment Station provided a trained man to live on the farm and have personal supervision of the tests. Mr. W. F. Ward, one of the authors of this publication, was stationed on the farm.

The weight of each steer was secured at the beginning and end of each test, and the total weight of each lot was noted every 28 days. When the steers were sold some of them had to be driven 9 miles to the shipping point at Scooba, Miss.. while others were driven 12 miles to Epes, Ala., for loading.

THE CATTLE AND THE PASTURE.

As far as possible grade Aberdeen-Angus, Shorthorn, Hereford, and Red Polled steers were employed; a few animals had a predominance of Jersey and scrub breeding. They were all bought of farmers in Sumter, Wilcox, Marengo, and neighboring counties, so they represented fairly accurately the average cattle of the western part of Alabama. In age they varied from 2 to 4 years. As will be seen later, the average weight at the beginning of the test was about 640 pounds. When compared with northern cattle it is seen that they were small, but they were as large as the average of the State.

The cattle were divided into two lots, one early and one late fattening, in each of the three years during which the experiment lasted. The early fattening lots had the designation lot F in each year, and the late fattening lots were called lot B. There were, therefore, three lots F and three lots B.

The summer pastures used in these experiments consisted of a mixture of sweet clover (Melilotus), Japan clover (Lespedeza), Johnson grass, crab grass, and some Bermuda grass. The sweet clover became available for grazing about April 1, while the Japan clover afforded practically no grazing until June 15. In some sections of the country sweet clover is considered a pest, as stock will not eat it, but in the South, or at least in Alabama, all kinds of stock eat it with great relish; they take to it as readily as to alfalfa.

The pasture was divided into fields, the size of each one depending upon the number of cattle grazed upon it, and also upon whether the steers were to be fed a light or a heavy supplementary feed. The object was to have an abundance of pasture for each lot of cattle. The early fattening lots of cattle (lot F) were turned on the pasture at a very early date, in fact before the grasses had become thoroughly established. The exact dates will be given later on.

The cattle were fed but once a day. This was done about sundown, so that they would all come out to the troughs, which were placed at convenient places in the pastures. No feed was thrown upon the ground.

No shelter, except trees, was provided, but the cattle did not suffer from the heat, as the pastures contained plenty of good shade trees. When a summer shade is provided cattle will suffer no more from heat in Alabama than they will in Illinois or Iowa.

While there were ticks in the pasture the cattle were not permitted to become badly infested with them; a dipping vat was used to keep down heavy infestation. In the three years' work, during which time 224 head of cattle were fattened, only one or two cases of Texas fever developed, and none of these was lost. In future work it is expected that the tick will be entirely eliminated.

QUALITY AND PRICE OF FEEDS.

The cottonseed cake was purchased upon the market, so an average market price was taken in making up the financial statements. It must be borne in mind, however, that prices vary from time to time and from place to place. For instance, cottonseed cake is valued at $26 a ton in this publication, but at the present writing (Dec. 20, 1911) cake can be purchased for $21 a ton. The price mentioned above, $26 a ton, very closely approximates the average price for the years 1909, 1910, and 1911. The pasture is valued at 50 cents per month per steer.

The cottonseed cake had been broken into nut size and sacked. This was done by the mill. The cake can be purchased in the large cake size, just as it comes from the press, for about $2 a ton less than the nut size. Some feeders find that it pays to break the cake on their own farms. As a whole, the cake was of excellent quality. Poor and damaged cake was fed a few times, when the good material could not be secured.

DAILY RATIONS.

The steers in lot B each year were fed longer than those in lot F, the object being to start lot F on feed a few weeks before lot B, and also to give the animals a heavier supplementary ration of cottonseed cake. This plan was followed out except in 1911. The spring of that year was an unusually dry one, and as a result the pastures were not ready for grazing as early as usual, consequently the lots were started on feed the same date but sold at different times. The steers in lot B were started on feed April 9 in 1909, April 7 in 1910, and April 21 in 1911. Those in lot F were started on feed March 19 in 1909, March 25 in 1910, and April 21 in 1911. The cattle in the B lot were sold August 26 in 1909, August 2 in 1910, and September 8 in 1911. Those in the F lot were sold August 5 in 1909, June 23 in 1910, and August 27 in 1911. Thus the steers in the B lot were fed an average of 137⅔ days, while those in the F lot were fed an average of 119⅔ days.

The pastures upon which the two lots of cattle grazed were not exactly similar throughout the whole test, as those in the F lot were started at an earlier date (except in 1911) than those in the B lot. As a matter of fact, the pastures in the case of the F lot were of very small value during the first two or three weeks of the tests; however, the experiment was outlined to learn whether it is profitable to start steers on feed during the very early spring months. On account of the fact that the pastures were short at this early date the cattle of the F lot were started on a rather heavy feed of cottonseed cake.

TABLE 22.—*Daily feed of cottonseed cake by periods of 28 days.*

Period.	Lot B (long feeding).			Lot F (short feeding).		
	Apr. 9 to Aug. 26, 1909.	Apr. 7 to Aug. 2, 1910.	Apr. 21 to Sept. 8, 1911.	Mar. 19 to Aug. 5, 1909.	Mar. 25 to June 23, 1910.	Apr. 21 to Aug. 27, 1911.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
First 28 days	2.35	2.21	2.88	3.24	3.27	3.40
Second 28 days	3.33	4.41	3.76	3.91	4.57	4.87
Third 28 days	3.54	3.80	3.72	4.82	5.00	4.97
Fourth 28 days	3.67	3.65	3.76	5.00	[1] 5.00	5.00
Fifth 28 days	3.83	[2] 3.50	[3] 3.76	5.00	....	[4] 5.00
Sixth 28 days	[5] 4.00	....	....	....	....	....

[1] For 7 days.
[2] For 6 days.
[3] For 29 days.
[4] For 17 days.
[5] For 14 days.

It is seen that the steers in the B lot were given from 2.21 to 2.88 pounds of cottonseed cake at the inauguration of the tests, while those in the F lot ate from 3.24 to 3.40 pounds each daily. At the close of the tests each steer in the B lot was consuming from 3.5 pounds to 4 pounds of cake, while those in the F lot were eating, on the average, 5 pounds daily. As a matter of fact there was practically no difference in the total quantity of cake fed to each steer in lots B and F, the main difference being that the steers in the F lot ate their amounts of feed in the fewer number of days.

While, to many feeders, the daily feed of cottonseed cake seems small, still reasonably good gains were secured when the size of the cattle is considered. The steers in the B lot averaged practically 600 pounds in weight at the inauguration of the tests, and an average daily gain of 1.87 pounds was secured. Those in the F lot were somewhat larger, averaging practically 690 pounds in weight, and an average daily gain of 2.04 pounds was obtained. Large amounts of cake are not required to obtain good gains when the cattle are grazing a reasonably good pasture. It is in any event impracticable to feed a heavy ration of cake along with pasture, as scours develop quickly when cottonseed cake is fed too freely. Scours occurred in fact in a few cases when no more than 5 pounds of cake was fed each steer daily. In the North and Northwest, where corn is cheap, it is practicable and usually profitable to supplement the pasture with a daily ration of from 15 to 18 pounds of corn daily for each steer, but there is no feed in the South cheap enough to be used in such large amounts.

TOTAL AND DAILY GAINS.

Table 23 outlines the initial and final weights and the gains of each lot, also the average total and daily gains of each steer.

TABLE 23.—*Weights and gains (summary of 3 years).*

Lot.	Number of steers.	Days fed.	Year.	Ration.	Initial weight of lot.	Final weight of lot.	Total gain of lot.	Average total gain of each steer.	Average daily. gain.
					Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
F (short period)..	35	140	1909	Pasture and cake	25,321	34,919	9,598	274.2	1.96
	30	91	1910	.....do...........	20,042	26,062	6,020	200.7	2.21
	25	128	1911	.....do...........	16,522	22,808	6,286	257.4	1.96
3-year average....	....	......	......	....	....	....	....	....	2.04
B (long period)...	75	154	1909	Pasture and cake	47,916	69,664	21,748	289.9	1.88
	34	119	1910	.....do...........	19,586	27,514	7,928	233.2	1.96
	25	140	1911	.....do...........	14,123	20,128	6,005	240.2	1.72
3-year average....	....	......	......	....	....	....	....	....	1.87

These cattle were from 2 to 4 years old, and small for their age. It should be remembered, however, that the initial weights were all taken at the close of the winter months, when the animals were in their lightest form. The steers in the F lot averaged 723, 668, and 661 pounds in weight at the inauguration of the pasture work in 1909, 1910, and 1911, respectively, while those in the B lot averaged 639, 576, and 565 pounds, respectively. The steers in the F lot, the short-fed ones, made an average daily gain of 1.96, 2.21, and 1.96 pounds in 1909, 1910, and 1911, respectively, or an average daily gain of 2.04 pounds for the three years. The steers in the B lot, the long-fed cattle, made an average daily gain of 1.88, 1.96, and 1.72 pounds in 1909, 1910, and 1911, respectively, or an average of 1.87 pounds for the three years. The steers in the F lot were fed a heavier ration of cottonseed cake than those in the B lot, and as a result gained more rapidly. When the size of the cattle is taken into account it is seen that the gains were satisfactory.

At the end of the feeding periods the steers in the F lot had attained an average weight of 998, 869, and 885 pounds in 1909, 1910, and 1911, respectively, while those in the B lot were somewhat smaller. For southern cattle they were of good size—larger than the average—but the southern markets prefer larger carcasses than these cattle produced, and will pay a premium for the large steers.

QUANTITY AND COST OF FEED REQUIRED TO MAKE 100 POUNDS GAIN.

Table 24 shows the number of pounds of feed required to make 100 pounds of gain in each case, the cost of the cottonseed cake to make the gains, and also the cost to make the increase in live weight when both the cake and the pasture are charged against the gains. It is seen that the increase in live weight during the fattening period was put on at a profit; that is, each pound added to the weight of the steers during the fattening period did not cost as much as it could be sold for on the market. This is an unusual state of affairs in fattening cattle, as under average winter conditions, and summer conditions, also, when a heavy supplementary grain feed is given, each pound of increase during the fattening period is made at a loss.

The economical gains in these tests were mainly due to two factors: First, the daily gains were satisfactory, notwithstanding the fact that only a small amount of high-priced feeds was consumed by each steer; and, second, the animals were grazing a pasture—the cheapest feed that can possibly be obtained in Alabama. When a large amount of concentrated feed is used to supplement the pasture the cost of the increase in weight will be much more expensive than was the case in these experiments.

TABLE 24.—*Quantity and cost of feed required to make 100 pounds of gain.*

Lot.	Number of steers.	Year.	Ration.	Cottonseed cake required to make 100 pounds of gain.	Cost to make 100 pounds of gain.	
					Cake.	Cake and pasture.
				Pounds.		
F (short period)	35	1909	Pasture and cake	224	$2.91	$3.76
	30	1910	do	197	2.56	3.32
	25	1911	do	244	3.17	4.02
			3-year average	220	2.86	3.69
B (long period)	75	1909	Pasture and cake	181	2.35	3.24
	34	1910	do	176	2.29	3.24
	25	1911	do	210	2.73	3.70
			3-year average	185	2.41	3.33

In the F lot it is seen that 224, 197, and 244 pounds of cottonseed cake were required to make 100 pounds of increase in live weight in the years 1909, 1910, and 1911, respectively, or, averaging the three years, 220 pounds of cake were eaten for every 100 pounds of gain. In the B lot 181, 176, and 210 pounds of cake were fed for every 100 pounds of gain in live weight in 1909, 1910, and 1911, respectively, or an average for the three years of 185 pounds. The saving of cottonseed cake in favor of the B lot was due to the fact that the steers in these lots were given a smaller daily allowance than those in the F lot.

The total expense in the F lot to make 100 pounds increase in live weight when the pasture and cake are both charged against the gains was $3.76, $3.32, and $4.02 in 1909, 1910, and 1911, respectively, or an average of $3.69 for the three years. The total cost to make the same gains in the B lot was $3.24, $3.24, and $3.70 in 1909, 1910, and 1911, respectively, or an average of $3.33 for the three years.

FINANCIAL STATEMENT.

As will be seen in the table below, the steers were purchased at various prices at the beginning of the tests. They cost from $2.95 to $3.50 per hundredweight, depending upon the size and quality of the steers and the year in which they were purchased. When the steers were ready for sale buyers came to the farm and purchased them on the farm, allowing for a 3 per cent shrink. In one case (lot B, 1909) they were sold as low as $3.90 per hundredweight on the farm; in no instance did they sell for more than $4.50 per hundredweight. After being sold they were shipped to various southern markets. Two or three loads were sent to Meridian, Miss., some were sent to Atlanta, Ga., while several carloads were shipped to New Orleans. The table below shows, among other things, the initial cost of the cattle each year, the selling price each year, and the total profit on each animal.

TABLE 26.—*Financial statement.*

Lot.	Number of steers.	Year.	Ration.	Initial price per hundredweight.	Initial cost of each steer.	Cost of feed eaten by each steer.	Total cost of each steer.	Selling price per hundredweight.	Selling price of each steer.	Profit on each steer.
F (short fed).	35	1909	Pasture and cake.	$3.20	$23.15	$10.33	$33.48	$4.375	$41.73	$8.25
	30	1910	.....do..........	3.20	21,38	6.64	28.02	4.50	37.92	9.90
	25	1911	.....do..........	3.50	23.13	9.98	33.01	4.50	39.82	6.81
			3-year average........	3.28+	22.55	9.08	31.63	4.45+	39.93	8.30
B (long fed)..	75	1909	Pasture and cake.	2.95	18.85	9.38	28.23	3.90	35.14	6.91
	34	1910	.....do..........	2.95	16.99	7.33	24.32	4.50	35.32	11.00
	25	1911	.....do..........	3.50	19.77	8.89	28.66	4.50	35.14	6.48
			3-year average........	3.05+	17.80	8.91	27.46	4.16+	35.19	7.73

It is seen that excellent profits were made in all the tests. In the F lot clear profits of $8.25, $9.90, and $6.81 were made on each steer in 1909, 1910, and 1911, respectively; an average profit of $8.30 was made on each animal. In the B lot clear profits of $6.91, $11, and $6.48 were made in 1909, 1910, and 1911, respectively. In these lots an average profit of $7.73 was secured on each steer; or, those cattle which were started on feed early, fed a heavy ration of cake along with the pasture, and marketed early in the summer months, returned a slightly greater total profit—$0.57 each—than the ones which were started on feed later and finished for the market at a late date. This is not a marked difference, however, in favor of the early method of feeding. The greatest advantage in favor of the early method of fattening cattle during the summer months is one that does not appear in a test of this kind. When the steers are disposed of at an early date the pastures can be grazed by a second bunch of cattle, or the grass has an opportunity to make an extra growth before cold weather sets in, thus affording extra feed for the winter months. With many farmers late pastures are of great value in saving winter feeds.

SUMMARY.

TABLE 27.—*Summary of averages.*

	Lot B (long fed).	Lot F (short fed).
	Pounds.	*Pounds.*
Average pounds of cottonseed cake eaten by each steer daily in 1909	3.40	4.39
Average pounds of cottonseed cake eaten by each steer daily in 1910	3.45	4.33
Average pounds of cottonseed cake eaten by each steer daily in 1911	3.60	4.66
Average daily gains for three years	1.87	2.04
Average number of pounds of cottonseed cake to make 100 pounds of gain	185	220
	Dollars.	*Dollars.*
Average cost of cottonseed cake to make 100 pounds of gain	2.41	2.86
Average total cost to make 100 pounds of gain (both pasture and cake included)	3.33	3.69
Average initial cost of steers per hundredweight	3.05+	3.28+
Average selling price of steers per hundredweight	4.16+	4.45+
Average profit on each steer	7.73	8.30

1. The object of this part of the work was to determine whether it is more profitable to feed steers a short or a long period of time when they are being fattened on pasture.

2. Grade Aberdeen-Angus, Shorthorn, Hereford, and Red Polled steers, with a few commoner ones, were used. They were bought in Sumter and neighboring counties and represented fairly accurately the average cattle of the western part of Alabama.

3. The steers were fed on pasture and cottonseed cake during the following periods of time:

Lot B (long fed): 1909, Apr. 9 to Aug. 26; 1910, Apr. 7 to Aug. 2; 1911, Apr. 21 to Sept. 8. Lot F (short fed): 1909, Mar. 19 to Aug. 5; 1910, Mar. 25 to June 23; 1911, Apr. 21 to Aug. 27.

4. The following average daily feeds of cake were given:

Lot B (long fed): 1909, 3.40 pounds; 1910, 3,45 pounds; 1911, 3.60 pounds. Lot F (short fed): 1909, 4.39 pounds; 1910, 4.33 pounds; 1911, 4.66 pounds.

5. The steers in the B lot made a daily average gain of 1.87 pounds, while those in the F lot gained at the rate of 2.04 pounds each day.

6. There were required 185 pounds of cottonseed cake to make 100 pounds of gain in the B lot, while 220 pounds of cake were eaten in the F lot to make the same gain.

7. When the pasture and cake are both charged against the gains, it cost $3.33 and $3.69 to make 100 pounds of gain in the B and F lots, respectively.

8. The steers in the B lot cost on an average $3.05+ per hundredweight at the beginning of the tests; they sold for $4.16+ per hundredweight at the close. The steers in the F lot cost $3.28+ per hundredweight and sold for $4.45+ per hundredweight.

9. Clear average profits of $7.73 per steer in the B lot and $8.30 per steer in the F lot were made.

10. An additional advantage in selling the cattle early is that the pastures have an opportunity to make an extra growth after the cattle are taken off, thus providing feed for the early winter months. In fact, this is probably the chief advantage to be secured in selling cattle at an early date.

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U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ANIMAL INDUSTRY.—BULLETIN 160.
A. D. MELVIN, CHIEF OF BUREAU.

THE CARE OF THE FARM EGG.

BY

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Animal Industry,
Washington, D. C., September 7, 1912.

Sir: I have the honor to transmit for publication as a bulletin of this bureau the accompanying manuscript entitled "The Care of the Farm Egg," by Messrs. Harry M. Lamon and Charles L. Opperman of the Animal Husbandry Division of this bureau. The work described is a continuation of the investigations into the egg trade which has been under way for several years.

In 1908 a careful survey of the conditions surrounding the trade was made, and the results were published as Circular 140, "The Egg Trade of the United States," wherein it was shown that there was a very heavy loss in the egg output, nearly all of which was attributed to improper methods of handling on the farm and at the country store. This loss was estimated to be fully 17 per cent of the total value, or $45,000,000 per annum.

In 1911 Bulletin 141, "The Improvement of the Farm Egg," was issued, one of the main objects of which was to emphasize the importance of the "loss-off" or quality system of trading in eggs. The present paper is supplemental to Bulletin 141 and makes a special feature of the value of producing infertile rather than fertile eggs.

Respectfully,

A. D. Melvin,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

INTRODUCTORY NOTE.

The egg investigations of 1910, which brought about the inauguration of the "loss-off" or quality system of buying eggs in Kansas, resulted in marked improvement in the quality of the eggs marketed from that State. The work of 1911 was devoted to keeping up the interest in the movement and to the study of the effect of farm conditions on the keeping quality of eggs, the results of which are presented herewith. The 1910 work emphasizes the effectiveness of organization as a means to improve the egg output of a community; the work of 1911 shows how the farmer may assure himself of maximum returns for his eggs by taking proper care of them and by proper management of his flock.

While the 1911 work was not, as some claim, a "discovery" of the superior keeping quality of the infertile egg, the authors deserve the credit for focusing public attention on the fact. Of the loss of $45,000,000 or more in the annual value of our egg crop, due to poor quality, at least one-third, or $15,000,000, is due to "blood rings." A blood ring is caused by the development of the embryo of a fertile egg subjected to heat and its subsequent death. No embryo can develop in an infertile egg, no matter how long it may be subjected to heat, because it is not fertile. Therefore a blood ring is impossible in the infertile egg; and by the removal of male birds from the flock as soon as the hatching season is over, and the segregation of young cockerels, no loss from blood rings will be experienced.

Unless cooled at once and kept cool, a fertile egg will spoil in hot weather almost as quickly as raw milk, and the purchaser of fertile eggs, even on the "loss-off" basis, whether he be the country-store merchant, the packer, or the consumer, has no assurance whatever against more or less loss. An infertile egg will keep; a fertile one will not. It therefore does not require a great stretch of the imagination to realize what effect the country-wide production of infertile eggs would have on our food supply.

Some of the loss due to "rots" and "spots," as shown in this bulletin, is caused by contamination in the nest and is largely, if not entirely, preventable. Both fertile and infertile eggs may be damaged in this way, although infertile eggs are less susceptible than fertile ones.

The propaganda work in Kansas has now been turned over to the Kansas State Agricultural College and Experiment Station at Manhattan, and the Animal Husbandry Division is now concentrating its efforts on the spread of the good-egg movement to other States, organizations having been effected already in Michigan and Minnesota. I firmly believe that if the egg-producing States generally will take up the matter of buying on a quality basis and the farmers are shown how to care for their eggs properly, especially to sell only infertile eggs during the summer months, the housewife will soon be able to observe a decided improvement in the quality of the eggs which she buys without having paid more for them than formerly. The means to improve the quality of the farm egg are so simple and inexpensive that anyone who keeps a flock of chickens should be able to apply them. In this connection the reader's attention is particularly directed to the five rules at the close of the bulletin.

In the investigations discussed in this bulletin the authors received a great deal of assistance from citizens of Kansas and from State officials, which has been greatly appreciated. Mr. Alfred R. Lee, of this division, also assisted part of the time in the investigation.

George M. Rommel,
Chief of the Animal Husbandry Division.

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THE CARE OF THE FARM EGG.

INTRODUCTION.

Since the poultry and egg industry of this country has assumed the enormous proportions indicated by the two last national censuses, 1900 and 1910, there has been a demand for and a growing interest in improved conditions and a need for a broader knowledge of the underlying principles of the industry. The State agricultural colleges and experiment stations have established departments of poultry husbandry for both teaching and research work. The experimental departments have given their attention to the various questions involved in the housing, feeding, breeding, and general management of poultry, while the instruction departments have built up practical courses in this branch of animal husbandry and have also assisted in disseminating the knowledge gained from the results of experimental work. Thus on every hand we can see an interest being manifested in improving the conditions in all branches of poultry work.

One of the most important of these is the production and marketing of eggs. Every year there is a loss of millions of dollars in bad eggs, the direct result of haphazard methods of production, marketing, and shipping which are now in vogue in many States. The greatest part of this loss is due mainly to ignorance or indifference on the part of the farmer and producer, and only a small part is caused by carelessness on the part of the buyer and shipper. In many instances the buyer is indirectly responsible, for when he buys eggs by the case-count system, as many of them do, he is encouraging the producer to be careless in gathering and marketing the eggs, since he pays him for anything that has an intact shell. The conscientious producer, however, will not try to shield himself under this pernicious system, so it is very much to his advantage to aid in the improvement of the commercial egg. He may not receive any extra compensation at the very start, but just as surely as he makes an organized effort to furnish the trade with strictly fresh eggs so surely will the competition in trade make it possible for him to dispose of his superior product at an increased profit.

It was with the view of determining the causes of the enormous loss in eggs, and if possible working out methods for its elimination, that the Department of Agriculture, through the Bureau of Animal

Industry, undertook a thorough investigation of the problem. Two publications,[1] one giving a bird's-eye view of the situation in several States and the other dealing specifically with the conditions in the State of Kansas, have already been issued. It was the knowledge gained through this general survey of conditions that suggested the undertaking of the experimental egg work set forth in the present paper.

THE GRADING OF EGGS.

Where eggs are handled in large quantities there are certain grades by which they are sorted and either retained for market purposes or rejected as useless. A brief description of these grades and the characteristics by which they are detected is given below.

Fresh egg.—An egg to be accepted as a first, or fresh egg, must be newly laid, clean, of normal size, showing a very small air cell, and must have a strong, smooth shell, of even color and free from cracks. With the exception of the air cell, which is only visible through the aid of the candle, these are the points by which eggs are graded in the early spring, at which time they are quite uniform in quality, thereby making candling unnecessary.

Checks.—This term applies to eggs which are cracked but not leaking.

Leakers.—As indicated by the name, this term applies to eggs which have lost a part of their contents.

Seconds.—The term "seconds" applies to eggs which have deteriorated to a sufficient extent as to be rejected as firsts. They are, however, of a high enough quality to be used for human consumption. The several classes of eggs which go to make up this grade may be defined as follows:

(*a*) Heated egg: One in which the embryo has proceeded to a point corresponding to about 18 to 24 hours of normal incubation. (See Pl. III, fig. 3.) In the infertile egg this condition can be recognized by the increased color of the yolk; when held before the candle it will appear heavy and slightly darker than in the fertile egg.

(*b*) Shrunken egg: This class of seconds can be easily distinguished by the size of the air cell. It may occupy from one-fifth to one-third of the space inside the shell. The holding of eggs for a sufficient length of time to allow a portion of the contents to evaporate is the main cause of this condition.

(*c*) Small egg: Any egg that will detract from the appearance of normal eggs on account of its small size will come under this class, although it may be a new-laid egg.

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[1] Hastings, Milo M. The egg trade of the United States. Bureau of Animal Industry Circular 140. Washington, 1909.

Lamon, Harry M., and Opperman, Charles L. The improvement of the farm egg. Bureau of Animal Industry Bulletin 141. Washington, 1911.

(*d*) Dirty egg: Fresh eggs which have been soiled with earth, droppings, or egg contents, or badly stained by coming in contact with wet straw, hay, etc., are classed as seconds.

(*e*) Watery egg: Those in which the inner membrane of the air cell is ruptured, allowing the air to escape into the contents of the egg, and thereby giving a watery or frothy appearance.

(*f*) Presence of foreign matter in eggs: In Plate III, figure 2, is given an excellent illustration of this class of eggs. The small dark streak across the yolk is a clot of blood. This condition is found in many fresh-laid eggs. Often eggs are laid which show small clots about the size of a pea. These are sometimes termed "liver" or "meat" spots.

(*g*) Badly misshapen eggs: Eggs which are extremely long or very flat, or in which part of the shell's surface is raised in the form of a ring; in other instances a number of hard wart-like growths appear on the outside of the shell.

Spots.—Eggs in which bacteria or mold growth has developed locally and caused the formation of a lumpy adhesion on the inside of the shell. There are three well-recognized classes of mold spots, namely, white, brown, and black. In cases where an infertile egg has been subjected to natural heat for a sufficient period of time, the yolk will often settle and become fixed to the membrane. This condition might be termed a "plain spot." In Plate VI, figures 3 and 4, are shown typical specimens of black mold and plain spot eggs.

Blood rings.—Eggs in which the embryo has developed to a sufficient extent so that it is quickly recognized when held before the candle. It has been found that it requires between 24 and 36 hours of incubation under a sitting hen to produce this condition. Good illustrations of these conditions are shown in Plate IV, figures 1 and 3, and in Plate V, figure 1.

Rots.—Eggs which are absolutely unfit for food. The different classes of rots may be defined as follows:

(*a*) Black rot: This is the easiest class of rots to recognize and consequently the best known. When the egg is held before the candle, the contents have a blackish appearance, and in most cases the air cell is very prominent. The formation of hydrogen-sulphid gas in the egg causes the contents to blacken and gives rise to the characteristic rotten-egg smell, and sometimes causes the egg to explode.

(*b*) White rot: These eggs have a characteristic sour smell. The contents become watery, the yolk and white mixed, and the whole egg offensive to both the sight and the smell. It is also known as the "mixed rot."

(*c*) Spot rot: In this case the foreign growth has not contaminated the entire egg, but has remained near the point of entrance. Such eggs are readily picked out with the candle, and when broken show lumpy particles adhering to the inside of the shell. These lumps are of various colors and appearances. It is probable that spot rots are caused as much by mold as by bacteria, but for practical purposes the distinction is unnecessary.

To all intents and purposes the spot rot as explained above is practically the same as the brown and black spots described under the general head of "Spots." The spot rot is also placed under the general head of rots simply because some candlers will call it a spot, while others designate it as spot rot. Pink and blood rots are names which are also applied to certain classes of rotten eggs, the pink rot deriving its name from the peculiar pinkish color of the contents when held before the candle. The same thing is true of the blood rot, which is bloody or red in appearance.

METHODS USED IN CONDUCTING THE EXPERIMENTS.

The plan of the work was to determine, in so far as could be shown by the candle, what deterioration took place in eggs when retained under actual conditions on the farms, in the country store, and during transportation. In choosing the field for the work careful consideration was given to the following points: A State where the production and marketing of eggs was an important factor, a location in that State where the cooperation of several farmers could be secured, and a town that was far enough from a central collecting point (or packing house) so that the effect of typical transportation conditions could be observed.

The eggs used in the various experiments were collected at a stated time each day from several farms and started in the experiment within an hour or two thereafter. Every egg was supposed to be absolutely fresh when entered in the experiments, and in all about 10,000 eggs were used during the season's work.

The six following classes of eggs were used: Clean fertile, dirty fertile, washed fertile, clean infertile, dirty infertile, and washed infertile.

Clean fertile eggs were normal fresh eggs produced by the farm flocks, on free range, with several mature male birds present during the entire season. Dirty fertile eggs were fresh eggs from the same flocks, but which before entering the experiments were artificially dirtied with barnyard mud to conform as nearly as possible with the natural dirty egg. Washed fertile eggs were fresh eggs from the above flocks which were thoroughly washed previous to being put in the experiments. In washing the eggs they were allowed to remain in a basin of water for a few moments and then well rubbed with an ordinary wash cloth and immediately dried with a towel. It is the general opinion that washed eggs do not keep as well as unwashed, and it was to determine this point that these eggs were used.

The three classes of infertile eggs used were identical with the fertile eggs, with the exception of being produced by flocks where the male birds were removed three weeks previous to using the eggs. It will be noted from the tables on the succeeding pages that experimental work with infertile eggs did not begin until after the 1st of June. This is due to the fact that under most farm conditions it would be impracticable to attempt to produce infertile eggs during the earlier spring months, as this is the season when the hatching and rearing of the coming year's flock must be attended to.

Every egg used was dated, which made it possible to secure a complete history of the egg from the time it was produced until it reached its final destination. This method of dating made each day's eggs in a given experiment a time experiment also. For example: A seven-day experiment having a given number of fresh eggs added each day, and these being dated, we obtained the influence of a certain environment for one, two, three, four, five, six, and seven days.

In Plate I, figures 1 and 2, is given a photographic reproduction of the thermographs used in connection with the work. The machine shown in figure 1 was located at the farm where the bulk of the work was carried on and used for recording the different temperatures and humidity. In figure 3 is a view of the apparatus in actual operation, the thermograph being inclosed in the box. The oilcloth covering was used to prevent the rain from entering the box and also to divert the direct rays of the sun. It was so arranged, however, that free circulation of air was not interfered with. A machine similar to that shown in figure 1 was used in the rooms of the dwelling house where certain experiments were conducted. The machine shown in figure 2 is constructed to record temperature only. It accompanied each shipment of eggs from the time it arrived at the country store, and while on the train, thereby furnishing a complete chain of temperature records for the experiments from the time the eggs were produced until they reached the packing house.

When the experiments were completed at the farm, which was in most cases seven days, the eggs were packed in ordinary 30-dozen cases, care being exercised to see that each experiment was kept separate. The transportation to town was by means of a team and buggy. After arriving in town, the eggs were candled immediately and an individual record made of the condition of each egg. This first candling represents the deterioration which occurred on the farm. The eggs were then repacked and held under typical country-store conditions for from 24 to 48 hours. The next operation was recandling, a similar record being made as above, showing the deterioration which took place while being held in the country store. They were then repacked and placed in an open stock car (the style of car used in that locality for shipping eggs and poultry) where they remained for about 12 hours before starting on their journey to the packing house, by local freight, a distance of 78 miles, requiring about 10 hours for the journey. The reason for placing the eggs in the car 12 hours previous to starting was due to the fact that the car was shipped early in the morning and it was often impossible for the merchants and local shippers to deliver the eggs at such an early hour.

After reaching the packing house the eggs were removed from the car in accordance with the usual custom and again candled. This third and last candling gave the deterioration which occurred during railroad transportation. The experiment, in so far as this paper is concerned, was then complete. The above methods of procedure were practically identical for all the experiments made during the entire season, and unless some special deviation occurred, no further mention will be made of them.

A sample candling report is here presented:

First town candling report. Date, June 8, 1911.

Date laid	June 1.	June 2.	June 3.	June 4.	June 5.	June 6.	June 7.	Total.
Firsts	3	2	3	3	4	5	5	25
Seconds	1	2	2	1	1			7
Cracked		1		1				2
Leakers								
Spots	1							1
Blood rings								
Rots								
Total	5	5	5	5	5	5	5	35

Second town candling report. Date, June 10, 1911.

Firsts	1	1	2	2	3	4	4	17
Seconds	3	3	3	2	2	1	1	15
Cracked		1		1				2
Leakers								
Spots	1							1
Blood rings								
Rots								
Total	5	5	5	5	5	5	5	35

Final candling report at packing house. Date, June 12, 1911.

Firsts			1	1	2	3	4	11
Seconds	4	4	4	3	3	2	1	21
Cracked		1		1				2
Leakers								
Spots	1							1
Blood rings								
Rots								
Total	5	5	5	5	5	5	5	35

In assembling the data connected with the work, the forms shown below were used. As will be seen upon inspection the card was used for recording the details concerning the experiment and the candling report for a record of the eggs. After being filled out, the card and report were fastened together and filed away for future reference.

[Front of card.]

[United States Department of Agriculture, Bureau of Animal Industry.]

POULTRY AND EGG MARKETING INVESTIGATIONS—HANDLING EGGS.

Observer.............................. Date........................ Experiment No...................
Statement of experiment..
....
Material used..
....
Eggs produced by.. Farmers' Card No..................
Date laid.................................... Where held...
Container and its condition....................................... How long held.........................
Date and hour left farm for market...
Haul to market or store by farmer: Time................................ Miles..........................
Container...
Wagon........................ Condition of road....................
Haul to market or store by egg collector or huckster: Card No............ Time.......... Miles.........
Container...
Wagon.............. Condition of road.............
Store or buyer to whom sold... Card No..............
Date received at store... How long held..........................
Where held............................... Container and its condition.................................
How packed for shipment..........................Kind and condition of cases and fillers..............
Date and hour left store for station............................ Length of haul...........................
Where held at station.................... How long held................ Covered or uncovered.........
Size of shipment..................................... Time put on car..................................
Kind of car............................ Eggs alone or eggs and poultry in car..........................
Length and time of railroad haul.................................. Reloaded.................................

[Back of card.]

Date and time of arrival at packing house...
How handled at packing house: How long before put in cooler.......... Temperature of cooler..........
Candling before or after cooling.................. Grading.................. Packing................
Time held.. How shipped.....................................
Date and hour put in car for shipment............. Kind of car............ Time of shipment......
To whom shipped................................. Date of shipment...............................
REMARKS...
....
....

DESCRIPTION OF THE EXPERIMENTS.

The question of selecting the proper conditions for the carrying out of the various experiments was one of vital importance, and it was only after careful consideration of the actual known conditions on the farms that the experiments described below were outlined. Experiments A and B were conducted with fertile and infertile dirty, washed, and clean eggs; Experiments C, E, F, and G with fertile and infertile clean and dirty eggs, while in Experiments D and H supposedly fertile eggs were used.

A. KEEPING EGGS IN DWELLING HOUSE.

The procedure followed in conducting an experiment with clean fertile eggs was as follows: Five eggs laid on a certain day were put in a clean receptacle (small grape basket) and placed in the parlor of the house (no artificial heat). Five fresh eggs were added each succeeding day until the experiment was completed at the farm, which was seven days in all cases except "stolen nest" and "under sitting hens." After once being put into the receptacle, the eggs were never removed from the room until they were packed and transferred to town. A constant record of temperature and humidity for the experiments was obtained by the use of a thermograph.

B. KEEPING EGGS IN CYCLONE CAVE.

The procedure for this experiment was identical with that given above, with the exception that instead of using a thermograph, an ordinary thermometer was employed, the temperature record being secured by reading three times daily. The use of the thermograph in this instance was unnecessary, as previous experience had shown that the temperature of the cave did not vary more than three or four degrees in a week, such a condition making it possible to procure a very accurate temperature record by the use of the thermometer.

In the section of the country where these experiments were conducted, many farmers did not have good, clean, dry cellars under their houses, but nearly all had what is known as "cyclone caves," in which are often kept the eggs produced on the farm. The conditions in many of these caves are as good as in the ordinary dry, unheated cellar. Plate II, figure 3, is a photograph of a cyclone cave, showing the entrance with doors open. These caves are often ventilated by a small window at the end opposite the door, and by a pipe leading through the top of the roof.

INEFFICIENT STORING FACILITIES ON THE FARM.

It has been pointed out in a previous publication (Bureau of Animal Industry Bulletin 141) that inefficient storage facilities on the farm are a serious difficulty with which the farmer's wife often has to contend, as a great many of the country homes in Kansas do not have dry, cool cellars, and when the thermometer begins to register from 100° to 106° F. there is no good place to keep perishable produce. To overcome this difficulty use is often made of the "cyclone cellar," or cave. In some instances these caves are of concrete construction throughout, and on such farms very little difficulty is experienced in keeping eggs in good condition. Some of these caves, however, are nothing more than oblong holes in the ground over which a rough gable roof is built. The soil which has been excavated to make the cave is thrown over this roof, and thoroughly packed so as to make it cool and practically waterproof. Caves of such construction are very hard to keep clean on account of the dampness and mold, which are always present when dirt walls and floor are used, and consequently they are very undesirable as a storage room for eggs. Dampness is conductive to the rapid development of mold and bacteria,

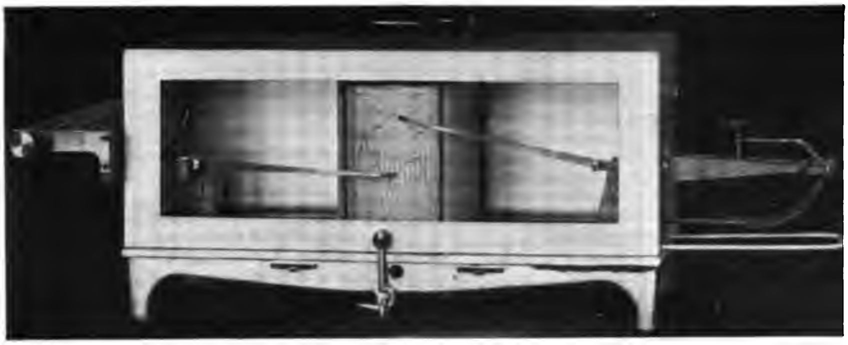

FIG. 1.—THERMOGRAPH RECORDING TEMPERATURE AND HUMIDITY.

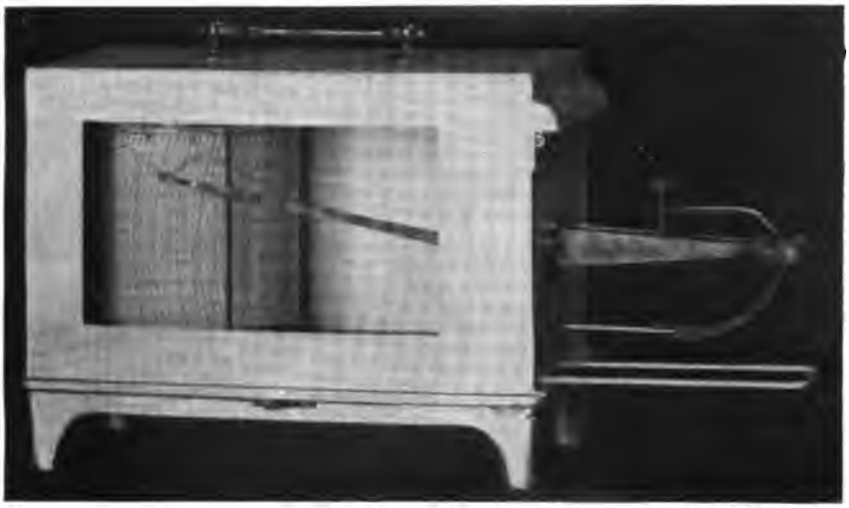

FIG. 2.—THERMOGRAPH RECORDING TEMPERATURE ONLY.

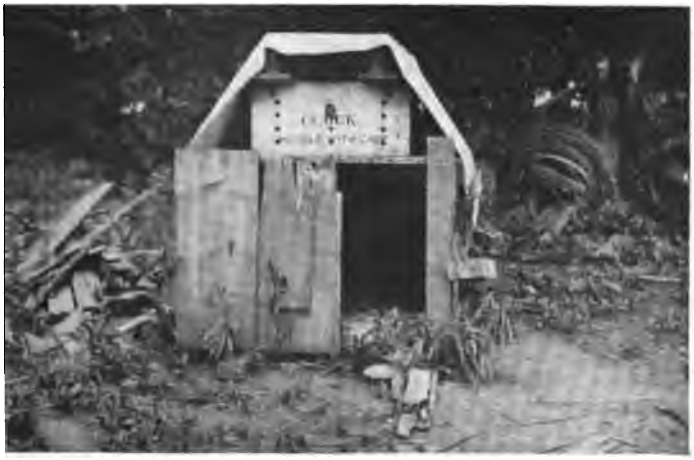

FIG. 3.—THERMOGRAPH IN OPERATION.

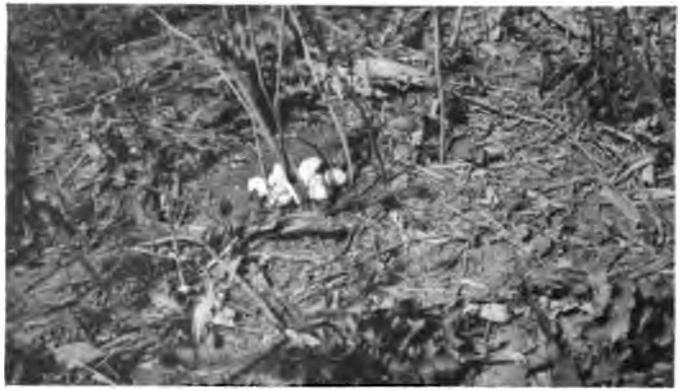

FIG. 1.—A TYPICAL WEED NEST

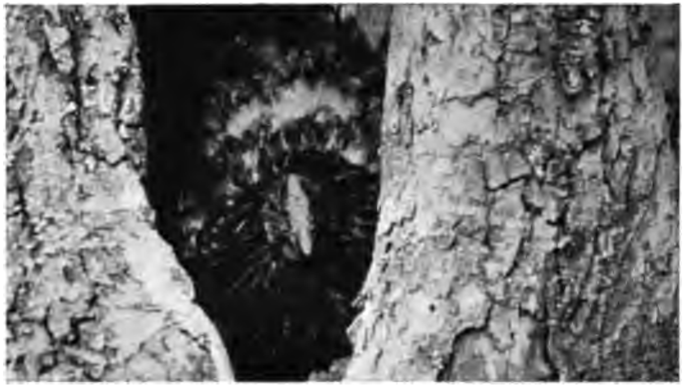

FIG. 2.—STOLEN NEST IN HOLLOW APPLE TREE.

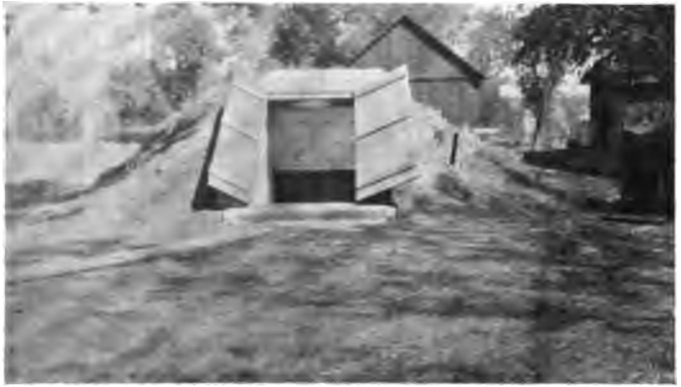

FIG. 3.—A CYCLONE CAVE.

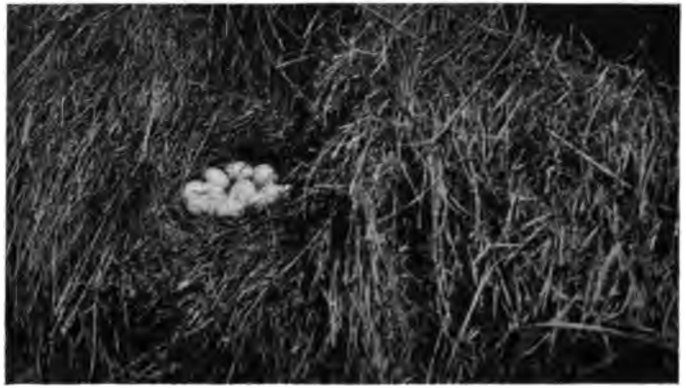

FIG. 4.—A NEST IN A STRAW STACK.

and consequently eggs kept in these caves are much more likely to show deterioration than if they were held in a dry room at the same temperature.

C. EGGS PLACED IN NESTS PROVIDED FOR LAYING HENS.

There can be no doubt of the fact that the annual loss in the United States on account of eggs becoming absolutely unfit for human food ("rots" and "spots") amounts to many millions of dollars. This much being conceded, the next problem is to ascertain when, where, and how this enormous deterioration is accomplished.

In this experiment, and in the others to follow, the object sought is definite knowledge as to the manner in which these inferior grades of eggs are produced. The fact that it is practically impossible, within a period of a few days and in normal weather, to produce spots and rots under the conditions of the two preceding experiments, made it necessary to typify in an experimental way the more abnormal conditions under which eggs might be subjected on the farm. Thus, in this experiment one of the bad effects due to infrequent gathering is seen.

With sitters in the flock.—On practically all farms during the spring and summer there are a certain number of broody hens which, if not used for hatching purposes, will spend more or less of their time sitting on the eggs in the nests utilized by the layers. This is true also, but in a less degree, even when an effort is made to break up the habit by taking the hens from the nests, during the day or at night, and placing them in yards or coops where there are no nests.

In this experiment the sitters were handled according to the usual custom on the farm—that is, they were removed from the nests every day or so and confined in a large coop for several days and then set at liberty. A daily record was kept of the number present on the nests so as to observe the rate of deterioration when few were present as compared with that when the sitters were numerous.

The method of conducting this experiment was as follows: Five eggs laid on a certain day were placed in several nests which were provided for the laying hens. Five fresh eggs were added each succeeding day until the experiment was completed at the farm. The time for this experiment was seven days. After the eggs were placed in the various nests they were not removed until packed and transferred to town.

No sitters on the nests.—After making provision for obtaining information as to the per cent of deterioration in eggs placed in nests for layers, with sitters present, it seemed desirable to investigate the problem from another standpoint, namely, that of a duplicate experiment having no sitters present. In this respect the cooperation of a farmer having a flock of White Leghorns was secured. This breed being nonsitters made it possible to carry out the desired project.

Care was exercised to see that any fowl showing a disposition to become broody was immediately confined. The method of conducting this experiment was exactly the same as that with the sitters on the nests.

D. PLACING EGGS UNDER SITTING HEN.

This experiment was instituted to determine accurately from a practical standpoint the period of time required to produce a blood ring that could be detected by the aid of the candle. Any changes occurring before this stage was reached were also observed and recorded. The experiment was divided into four parts, showing the influence of natural incubation for 24 hours, 36 hours, 48 hours, and 72 hours.

The procedure for the tests was as follows: From 10 to a dozen fresh fertile eggs were placed under a sitting hen and allowed to remain there for the specific time required by the test. They were then removed to the room in the dwelling house where Experiment A was carried on, and kept there until the experiment was completed at the farm. As soon as one lot of eggs was removed from under the hen a fresh lot was substituted, and the experiment carried on continually in this manner. Separate tests with infertile eggs were also carried on.

E. PLACING EGGS UNDER CORNCRIB.

In this experiment five clean, fertile, new-laid eggs were placed on the earth underneath the corncrib, and protected by means of an open-mesh wire hood. Five fresh eggs were added for each successive day until the experiment was completed at the farm. The eggs were never removed from under the corncrib until the experiment was ended.

F. EGGS PLACED IN NESTS IN WEEDS OR UNDERBRUSH.

In selecting the location for these nests care was exercised to have the conditions as natural as possible, and in most cases the locations decided upon were those that had already been chosen by the hens themselves. In conducting the experiment the following methods were used: Five clean fertile eggs laid that day were placed on the earth in the weeds or underbrush, and protected by means of an open-mesh wire hood. Five fresh eggs were added for each successive day until the experiment was completed at the farm, the time in this case being seven days. The eggs after being placed in the nests were never removed until packed and transferred to town.

G. EGGS PLACED IN NEST ON STRAW STACK.

The procedure in this case was similar to that given in the preceding experiment, with the exception that the eggs were put in nests on the straw stack instead of on the earth.

H. EGGS PLACED IN STOLEN NEST.

It is a common occurrence for the farm hen to locate her nest in some out-of-the-way place which is not likely to be discovered. These are designated "stolen nests." After choosing a location, she will lay from 10 to 15 eggs, and then start to sit. It often so happens that after sitting on the eggs for several days she will become indisposed and abandon the nest. In due course the eggs will be discovered by some of the members of the household, and if they are not educated as to what constitutes a good egg, they will put them in with the rest of the eggs that are sent to market. This is one of the channels through which thousands of dozens of bad eggs are placed on the market.

To secure knowledge concerning the quality of these eggs, the following method was adopted: After locating a stolen nest, the eggs of unknown history would be removed and a marked nest egg left. From that time on the nest was visited each day, and the eggs dated as they were laid. The hen was allowed to lay until she started to set, at which time the eggs were removed and transferred to town, where they were candled. The object was not to note the effect of steady incubation, but rather the condition of the eggs just previous to the time the hen would desire to set. Such data as temperature, rainfall, and the number of clear days were carefully recorded for each experiment.

RESULTS OF THE EXPERIMENTS.

Before discussing the results of the various experiments, it will be well to outline briefly the system followed in condensing the tables. In the Appendix at the end of this bulletin are given the detailed data from which the condensed tables referring to the cyclone-cave experiment were compiled. It may here be noticed that experiments Nos. 43, 44, and 45 all began on May 13 and ended at the farm on May 20. Each of these experiments, however, had to do with a certain class of fertile eggs with which tests were being conducted in the cave. In the condensed reports (see Tables 1, etc.) we have the total results for a part of the season, June 17 to August 26, for the fertile and infertile eggs of each of these different experiments given in the same general form as that used for recording the data of a seven-day experiment in the Appendix. In drawing conclusions from the condensed reports, it is obvious that cognizance can not be taken of the specific deterioration occurring in an experiment during a seven-day period of extremely hot or moderately cool weather. This point, however, will be taken up in another part of the paper. The fact that the results of the condensed reports are a true representation of the loss which the producer who allowed the eggs to remain in any of the various conditions would have to bear, makes it possible to reach conclusions that have a practical application.

The price allowed in this work for first, or fresh, eggs is 15 cents per dozen, and for seconds and cracks, 9 cents. Leakers, spots, blood rings, and rots are figured as a total loss. The above prices will correspond favorably with those allowed by buyers who purchased on the loss-off system during the season that the experiments were conducted. The per cent of loss which is given in the last column of the table is figured from the actual loss in dollars and cents, since this is the only basis by which the loss borne by the producer can be aptly represented. Loss at the packing house represents total loss from farm to packing house.

The reader will recall that in the descriptions of the different experiments mention was made of carrying on tests with dirty fertile and infertile eggs in some of the experiments. This was done for several weeks at the beginning of the season, but the results obtained were not considered of enough importance to continue them as first planned, and it was decided to continue them in the "house" and "weed-nest" experiments only. This was done in order that whatever difference there might be in the keeping qualities of dirty and clean eggs might be observed, and the retention of them in one inside and one outside experiment was considered sufficient to furnish such data as were desired.

A. THE HOUSE EXPERIMENTS.

The results obtained from the house experiments, as set forth in Table 1, may be noted as follows:

1. That all classes of eggs kept in this environment showed a much higher per cent of loss than those which were kept in the cyclone cave. This increased loss is accounted for by the fact that the daily maximum temperature in the house was from 15° to 40° higher than that of the cave. In the former the maximum temperature on two occasions reached 114° F., while in the latter it never exceeded 70° F.

2. The class of eggs wherein the greatest per cent of loss occurred was that of dirty fertile, although the clean fertile were less than one-half of 1 per cent less. In no way, however, can this slightly increased deterioration be attributed to the fact that the eggs were dirty, for in practically every instance the development of floats, blood rings, and rots were the causes of loss. Again, the variations in the losses of clean fertile, washed fertile, and dirty fertile were so slight when compared to each other that it would be impossible to say that the decreased or increased deterioration was caused through the eggs being clean, washed, or dirty.

3. That clean infertile eggs, as was the case in the cave experiments, again proved superior to all other classes, the loss at the packing house

being from 17 to 25 per cent less than in the classes of fertiles, which decrease is due mainly to the absence of spots, blood rings, and rots.

In view of the fact that infertile eggs should be sterile, it may seem peculiar to the reader that the above grades manifested their presence in this class of eggs. This may be explained, however, by the fact that after the middle of August the activity of the young cockerels is such that it is rather difficult to find a farmer who has a flock of chickens that are producing 100 per cent of infertile eggs. It is a condition that exists under practical conditions and cognizance of it must therefore be taken in a problem of this nature. In other words, it would detract from the value of the work to use 100 per cent infertile eggs at the season of the year when the farmer has to contend with a certain per cent of fertile ones. The farmer must retain a certain number of cockerels for breeding purposes, and if he is to produce strong vigorous males it is obvious that they can not be confined in small coops or yards.

4. Of the three classes of infertile eggs, the variations in loss are of such a minor nature that they can not be regarded as significant.

5. A comparison of the percentage of seconds in the three classes of fertile eggs with those in the same classes of infertile will show that during the seven days the eggs were held at the farm the fertile eggs produced the greatest proportion of seconds. This is also true of the second candling, but in the third and final candling the percentage of seconds was greater in the infertile eggs. This apparent decrease in the fertile seconds is due to the fact that many of the eggs which were seconds just before leaving town deteriorated to such an extent during transportation that they were graded as blood rings, etc., when candled at the packing house. This change, of course, did not take place in the infertile classes, which clearly explains the variation. As has been mentioned before, the infertile seconds were far superior to the fertile.

The results of this experiment may be briefly summarized in the following statements:

(*a*) An unheated room in a dwelling house is not as good a place to keep eggs as the cyclone cave, or dry, unheated cellar.

(*b*) The condition of clean infertile eggs, when candled at the packing house, was better than that of any other class.

(*c*) The keeping qualities of the three classes of fertile eggs are practically the same, which is also true for infertile during the time of the experiment.

(*d*) If the producer is to realize the maximum returns, he can not afford to keep fertile or infertile eggs in the house during the warm season.

TABLE 1.—*Condensed report of seven-day experiments with eggs kept in parlor of dwelling house.*

Time.	Total eggs and condition.	When candled.	Results of candling.														Total eggs candled.	Original value of eggs at 15 cents per dozen.	Loss.	
			Firsts.		Seconds.		Cracked.		Leakers.		Spots.		Blood rings.		Rots.					
			No.	*P.ct.*	*No.*	*P.ct.*	*No.*	*P.ct.*	*No.*	*P.ct.*	*No.*	*P.ct.*	*No.*	*P.ct.*	*No.*	*P.ct.*		*Dollars.*	*Dollars.*	*Per ct.*
June 17 to Aug. 26.	350, clean fertile	On arrival in town	146	42.1	169	48.7	3	0.9	0	0	0	0	29	8.4	0	0	347	4.34	1.22	28.2
		Before leaving town	106	30.5	180	51.9	7	2.0	0	0	0	0	53	15.3	1	.3	347	4.34	1.61	37.1
		Arrival at packing house	92	26.5	154	44.4	7	2.0	0	0	1	.3	53	15.3	40	11.5	347	4.34	1.98	45.6
Do	210, washed fertile.	On arrival in town	103	49.5	85	40.9	2	1.0	0	0	0	0	17	8.2	1	.5	208	2.60	.67	25.8
		Before leaving town	78	37.9	100	48.6	1	.5	0	0	0	0	25	12.1	2	1.0	206	2.58	.85	33.0
		Arrival at packing house	66	32.2	92	44.9	6	2.9	0	0	0	0	23	11.2	18	8.8	205	2.57	1.00	38.9
Do	210, dirty fertile	On arrival in town	81	38.4	111	52.6	3	1.4	0	0	0	0	16	7.6	0	0	211	2.64	.77	29.2
		Before leaving town	56	26.5	120	56.9	3	1.4	0	0	0	0	32	15.2	0	0	211	2.64	1.02	38.7
		Arrival at packing house	51	24.3	97	46.2	6	2.9	0	0	2	1.0	33	15.7	21	10.0	210	2.63	1.21	46.0
Do	350, clean infertile.	On arrival in town	246	70.5	94	26.9	8	2.3	1	.3	0	0	0	0	0	0	349	4.36	.52	11.9
		Before leaving town	199	57.5	138	39.9	9	2.6	0	0	0	0	0	0	0	0	346	4.32	.74	17.1
		Arrival at packing house	164	47.4	171	49.4	9	2.6	0	0	1	.3	1	.3	0	0	346	4.32	.92	21.3
Do	210, dirty infertile.	On arrival in town	143	69.1	63	30.5	1	.5	0	0	0	0	0	0	0	0	207	2.59	.32	12.4
		Before leaving town	105	50.7	101	48.8	1	.5	0	0	0	0	0	0	0	0	207	2.59	.51	19.7
		Arrival at packing house	98	47.5	103	50.0	3	1.5	0	0	1	.5	1	.5	0	0	206	2.57	.55	21.4
Do	210, washed infertile.	On arrival in town	129	61.4	77	36.7	4	2.0	0	0	0	0	0	0	0	0	210	2.63	.41	15.6
		Before leaving town	114	54.3	90	42.9	4	2.0	0	0	0	0	1	.5	1	.5	210	2.63	.49	18.6
		Arrival at packing house	89	42.4	100	47.6	6	2.9	0	0	0	0	14	6.7	1	.5	210	2.63	.72	27.4

NOTE.—A comparison of the figures under column headed "Total eggs and condition" with those under column "Total eggs candled" will often show a variation. This variation is due to eggs being broken or lost.

B. THE CYCLONE-CAVE EXPERIMENTS.

A perusal of Table 2, which deals with eggs retained in a cyclone cave, will show the following important points: (1) That with all classes of eggs, both fertile and infertile, there was practically no loss from the time the eggs were produced until they left town for the packing house, and after reaching the packing house the greatest loss, which was in the clean fertile class, did not exceed 19.8 per cent of the total value of the eggs. (2) That the loss occurring in clean and washed fertile eggs is nearly the same. A result of this kind would indicate that fertile eggs which had become soiled in the nest could be washed and retained in the cave without any serious deterioration taking place if the operation was performed in the manner herein described. It must be borne in mind, however, that in this case, while washed eggs stored under good conditions apparently kept as well as unwashed, the fact that contact with water tends to remove or dissolve the mucilaginous coating of the eggshell, thereby lessening the resistance to the invasion of molds and bacteria and also allowing more rapid evaporation of the contents, makes such eggs inferior for storing purposes when compared with clean eggs. (3) That the infertile eggs proved their superior keeping qualities over all others. The important point to be brought out in connection with infertile eggs is that the absence of fertilization makes it impossible for such eggs to develop into blood rings or chick rots, while in the fertile eggs these grades of deteriorated eggs comprise the great bulk of the loss. While the number and percentage of infertile seconds is only 10 per cent less than that of fertile, it is important that we thoroughly understand the great difference which exists in the quality of these two classes of seconds. For example, it will be sufficient to say that from 90 to 95 per cent of the infertile seconds were so designated on account of a slight shrinkage in the contents of the eggs, thereby causing the air cell to appear larger than that found in the fresh egg, while with the fertile seconds there was a very noticeable deterioration or change brought about by the development of the living embryo. In other words, there occurs no change in the former which would tend to render the egg unfit for food, while in the latter the composition of the egg is undergoing a marked change through the development of life within the egg. These differences are well illustrated in Plates III, IV, and V. Furthermore, it may here be stated that the great differences in fertile and infertile seconds were much more noticeable when the eggs were kept under other conditions than in the cave experiments.

The conclusions, so far as may be drawn from the data at hand are, first, that all classes of eggs retained in the cyclone cave showed a very small percentage of loss from the time they were produced until they reached cold storage. Second, that clean infertile eggs proved superior to all other classes, and washed infertiles second best. Third, that clean and washed fertile eggs compared favorably with the same classes of infertile while retained in the cave, but showed a tendency to deteriorate more rapidly during transportation from farm to packing house.

C. EXPERIMENTS WITH EGGS PLACED IN NESTS FOR LAYERS.

From Table 3, which shows the results of these experiments, we may note the following points:

1. In both the experiments with clean fertile eggs the resulting loss was far in excess of any other condition. In the first case, where sitters were present, the high rate of deterioration is due to the more or less constant sitting of broody hens on the nests, while in the latter it was caused by a scarcity of nests. There were no sitters present in the latter, but the fact that 8 or 10 hens would lay in the same nest daily brought about practically the same condition, and, as will be observed from the table, the total loss was even greater in the latter instance.
2. A comparison of the total losses for fertile and infertile eggs will show that in the former class when sitters were not present the loss was 38.6 per cent greater than that in the infertile, and where sitters were present the loss was 32.8 per cent greater. The bulk of the loss in the two fertile-egg experiments was caused by the development of blood rings and rots, while in the infertile it was due to seconds.
3. The infertile eggs proved to be more resistant to deterioration than the fertile when placed in nests for layers with the sitters present. The total loss at the packing house for fertiles (sitters present) was 64.2 per cent and for infertiles under the same conditions only 31.4 per cent. It must also be remembered that the quality of the infertile eggs was superior to the fertiles, since the seconds, which comprise the bulk of the loss in this class, are so designated simply because they show a slight shrinkage of contents and in some instances a little heat. Figures 3 and 4 in Plate III illustrate the difference between the fertile and infertile seconds of this experiment.

The conclusions for this test may be summarized as follows: First, irregularity in gathering the eggs from the nests used by the layers is one of the ways in which a serious loss in the quality of the egg may occur on the farm. Second, infertile eggs are the most resistant to this condition. Third, the greatest loss in fertile eggs occurred in the test when sitters were not present. The reason for this has been explained, and it is quite probable that even in instances when one nest was provided for every four or five hens the loss resulting from irregularity in gathering the eggs would be about as serious as that where sitters are present.

TABLE 2.—*Condensed report of seven-day experiments with eggs kept in cyclone cave.*

Time.	Total eggs and condition.	When candled.	Results of candling.														Total eggs candled.	Original value of eggs at 15 cents per dozen.	Loss.	
			Firsts.		Seconds.		Cracked.		Leakers.		Spots.		Blood rings.		Rots.					
			No.	*P. ct.*	*No*	*P. ct.*	*No.*	*P. ct.*	*No.*	*P. ct.*	*No.*	*P. ct.*	*No.*	*P. ct.*	*No.*	*P. ct.*		*Dolls.*	*Dolls.*	*Per ct.*
June 17 to Aug. 26.	455, clean fertile	On arrival in town	410	90.3	30	6.6	14	3.1	0	0	0	0	0	0	0	0	454	5.67	0.22	3.9
		Before leaving town	367	81.0	72	15.9	14	3.1	0	0	0	0	0	0	0	0	453	5.66	.43	7.6
		Arrival at packing house	255	56.8	167	37.2	22	4.9	0	0	2	.4	3	.7	0	0	449	5.61	1.11	19.8
Do	273, washed fertile.	On arrival in town	253	93.7	12	4.5	4	1.5	0	0	0	0	1	.4	0	0	270	3.38	.09	2.7
		Before leaving town	227	84.1	35	13.0	7	2.6	0	0	0	0	1	.4	0	0	270	3.38	.22	8.3
		Arrival at packing house	167	61.6	97	35.8	6	2.2	0	0	0	0	1	.4	0	0	[1] 271	3.39	.52	15.3
Do	455, clean infertile.	On arrival in town	442	97.2	4	.9	8	1.8	0	0	0	0	0	0	1	.2	455	5.69	.07	1.2
		Before leaving town	432	95.2	14	3.1	8	1.8	0	0	0	0	0	0	0	0	454	5.67	.11	1.9
		Arrival at packing house	325	71.6	115	25.4	12	2.7	2	.4	0	0	0	0	0	0	454	5.67	.65	11.5
Do	273, washed infertile.	On arrival in town	259	95.3	10	3.7	3	1.1	0	0	0	0	0	0	0	0	272	3.40	.06	1.8
		Before leaving town	255	93.8	13	4.8	4	1.5	0	0	0	0	0	0	0	0	272	3.40	.08	2.4
		Arrival at packing house	195	72.5	72	26.8	2	.7	0	0	0	0	0	0	0	0	269	3.36	.37	11.0

[1] Extra egg recorded at packing house.

NOTE.—A comparison of the figures under column headed "Total eggs and condition" with those under column "Total eggs candled" will often show a variation. This variation is due to eggs being broken or lost.

TABLE 3.—*Condensed report of seven-day experiments with eggs placed in nests for layers.*

Time.	Total eggs and condition.	When candled.	Results of candling.														Total eggs candled.	Original value of eggs at 15 cents per dozen.	Loss.	
			Firsts.		Seconds.		Cracked.		Leakers.		Spots.		Blood rings.		Rots.					
			No.	*P. ct.*	*No.*	*P. ct.*	*No.*	*P. ct.*	*No.*	*P. ct.*	*No.*	*P. ct.*	*No.*	*P. ct.*	*No.*	*P. ct.*		*Dolls.*	*Dolls.*	*Per. ct.*
May 20 to Aug. 26.	497, clean fertile (sitters present).	On arrival in town	77	15.7	248	50.6	6	1.2	0	0	0	0	132	26.9	27	5.6	490	6.12	3.26	53.3
		Before leaving town	49	10.0	231	47.2	11	2.3	0	0	0	0	156	31.9	42	8.6	489	6.11	3.41	55.8
		Arrival at packing house	58	11.9	186	38.3	7	1.4	1	0.3	1	0.3	124	25.5	109	22.4	486	6.08	3.90	64.2
May 23 to Aug. 26.	479, clean fertile (no sitters).	On arrival in town	60	13.2	210	46.1	10	2.2	0	0	0	0	142	31.2	34	7.5	456	5.70	3.30	58.0
		Before leaving town	33	7.2	195	42.8	11	2.4	0	0	0	0	165	36.2	52	11.4	456	5.70	3.74	65.6
		Arrival at packing house	31	6.8	164	36.2	5	1.1	1	.2	3	.7	127	28.0	123	27.1	454	5.67	4.01	70.8
May 20 to Aug. 26.	479, clean infertile (sitters present).	On arrival in town	230	49.0	216	46.0	12	2.6	0	0	0	0	10	2.1	2	.4	470	5.87	1.29	22.0
		Before leaving town	167	36.2	265	57.4	14	3.0	1	.2	0	0	12	2.6	3	.7	462	5.78	1.60	27.7
		Arrival at packing house	129	28.2	295	64.6	15	3.3	0	0	0	0	13	2.9	5	1.1	457	5.71	1.78	31.4

NOTE.—A comparison of the figures under column headed "Total eggs and condition" with those under column "Total eggs candled" will often show a variation. This variation is due to eggs being broken or lost.

D. THE SITTING HEN EXPERIMENTS.

The chief value of this experiment lies in the fact that the results obtained enable us to state accurately the least time required to render a fertile egg unfit for food.

1. Fertile eggs after being incubated under a sitting hen for 24 hours developed into what is known to the trade as light floats. The only change manifested in infertile eggs under the same conditions was a slight shrinkage in the contents, thereby causing the air cell to appear larger than that found in the fresh laid egg.
2. In the 36-hour test it was very apparent that some time between 24 and 36 hours of incubation the blood commences to assume sufficient prominence so that it can be detected when held before the candle. After being allowed to die, the embryo takes on an appearance as shown in Plate IV, figure 1, where it will be seen that the blood settles toward the edge of the yolk, forming an irregular circle. In infertile eggs, with the exception that the air-cell is necessarily larger, the change is practically the same as that explained above in the 24-hour test.
3. That in the 48 and 72 hour tests (see Plate IV, fig. 3) the appearance of the fertile eggs, in relation to the formation of blood, is similar to that found after 36 hours except that the development is much more marked. In Plate V, figure 1, is shown a living embryo after 72 hours of incubation, and in Plate VI, figure 1, the same egg after life had become extinct. Infertile eggs which have been subjected to this amount of incubation are similar in appearance to that shown in Plate V, figure 2. They do, however, show an increased amount of shrinkage, or enlargement of the air cell, as incubation proceeds.

The conclusion to be drawn from this investigation is that after 36 hours of incubation there is a sufficient quantity of blood present in a fertile egg when held before the candle to be detected by the naked eye.

It may be noted that there is no table accompanying this experiment. The photographic representations given in Plates III, IV, V, and figures 1 and 2 of Plate VI present the case so forcibly that no tabular data are needed. These pictures show conclusively how rapidly fertile eggs deteriorate under a sitting hen, and they also show the great superiority of infertile eggs under these conditions.

E. THE CORNCRIB EXPERIMENT.

The conditions of the two experiments just discussed were, so to speak, normal, while those of this experiment and of the succeeding ones are abnormal. The object in the former case was to ascertain which of the two places was most conducive to good quality in eggs, while in the latter case definite knowledge as to where and how the great mass of bad eggs are produced was sought. If the producer is to be educated along these lines, it is desirable that we not only determine where eggs keep well, but also that we point out the possible conditions that may give rise to a great number of bad eggs. Such information may enable him, if he so desires, to eliminate certain undesirable conditions and thereby increase the production of good marketable eggs.

From the data in Table 4 we may note the following points: A comparison of the losses in clean fertile and infertile eggs kept under a corncrib will show that the latter class was more resistant to the environmental conditions of the experiment. This is particularly noticeable in the grades of spots, blood rings, and rots, where the infertile egg, on account of its keeping qualities, could not deteriorate because of the development of life within it. It will be remembered that spots, blood rings, and rots are a total loss, and in the clean fertile eggs 25.1 per cent of the total number were classed under these grades, while in the clean infertile only 2.4 per cent were discarded for like deterioration. As has been mentioned before, the activity of the young cockerels was the cause of a small per cent of fertility in the supposedly infertile eggs.

A comparison of the seconds in the two classes will show a similar condition to that just explained in the "House experiment."

To sum up briefly, we may say that when kept on the earth under the corncrib, clean infertile eggs retained the qualities described in eatable eggs better than those which were fertile.

TABLE 4.—*Condensed report of seven-day experiments with eggs kept under corncrib.*

Time.	Total eggs and condition.	When candled.	Results of candling.														Total eggs candled.	Original value of eggs at 15 cents per dozen.	Loss.	
			Firsts.		Seconds.		Cracked.		Leakers.		Spots.		Blood rings.		Rots.					
			No.	*P. ct.*	*No.*	*P. ct.*	*No.*	*P. ct.*	*No.*	*P. ct.*	*No.*	*P. ct.*	*No.*	*P. ct.*	*No.*	*P. ct.*		*Dolls.*	*Dolls.*	*P. ct.*
June 10 to Aug. 26.	385, clean fertile...	On arrival in town..........	151	40.9	194	52.6	2	0.5	0	0	0	0	22	6.0	0	0	369	4.61	1.25	27.1
		Before leaving town..........	89	24.1	227	61.6	5	1.4	0	0	0	0	47	12.7	1	.3	369	4.61	1.76	38.2
		Arrival at packing house..........	100	27.3	171	46.6	4	1.1	0	0	3	.8	59	16.1	30	8.2	367	4.59	2.02	44.0
Do.....	385, clean infertile.	On arrival in town..........	266	70.2	108	28.5	5	1.3	0	0	0	0	0	0	0	0	379	4.74	.56	11.8
		Before leaving town..........	206	54.6	163	43.2	7	1.9	0	0	0	0	1	.3	0	0	377	4.71	.86	21.0
		Arrival at packing house..........	172	45.6	186	49.4	10	2.7	0	0	1	.3	6	1.6	2	.5	377	4.71	1.09	23.2

NOTE.—A comparison of the figures under column headed "Total eggs and condition" with those under column "Total eggs candled" will often show a variation. This variation is due to eggs being broken or lost.

F. THE WEED-NEST EXPERIMENT.

From the data in Table 5 we note:

1. That of the three classes of eggs with which tests were carried on in the weed nests dirty fertile suffered the greatest loss. It is noticeable, however, that the difference in loss between clean and dirty fertile is very slight.

2. The development of blood rings and rots in both classes of fertile eggs was the main cause of the heavy loss. While it is true that the seconds are responsible for a part of this loss, the actual figures for the 385 clean fertile eggs would be 81 cents loss for seconds and cracked, and a combined loss of $1.23 for spots, blood rings, and rots. In the case of the 231 dirty fertile eggs, the figures would be 50 cents loss for seconds, and 74 cents for the blood rings and rots, which proves that the burden of the loss must be credited to the spoiled eggs.

3. A comparison of the losses at the packing house (see last column of the table) gives superiority to the clean infertiles by a margin of 21.8 per cent, again demonstrating that infertile eggs possess in a much higher degree those qualities which tend to make them resistant to undesirable keeping conditions.

The conclusions which may be reached from this experiment are: First, that fertile eggs which might be laid in nests in the weeds and not discovered for several days can easily develop into spots, blood rings, and rots during the warm weather. Second, that infertile eggs under the same conditions do not deteriorate to the extent of fertiles. Third, that of all clases, clean infertile were in the best condition when candled at the packing house.

TABLE 5.—*Condensed report of seven-day experiments with eggs kept in weed nest.*

Time.	Total eggs and condition.	When candled.	Results of candling.														Total eggs candled.	Original value of eggs at 15 cents per dozen.	Loss.	
			Firsts.		Seconds.		Cracked.		Leakers.		Spots.		Blood rings.		Rots.					
			No.	*P. ct.*	*No.*	*P. ct.*	*No.*	*P. ct.*	*No.*	*P. ct.*	*No.*	*P. ct.*	*No.*	*P. ct.*	*No.*	*P. ct.*		*Dolls.*	*Dolls.*	*P. ct.*
June 10 to Aug. 26.	385, clean fertile...	On arrival in town..................	129	35.3	216	59.0	7	1.9	0	0	0	0	14	3.8	0	0	366	4.58	1.35	29.5
		Before leaving town..............	85	23.3	222	60.8	10	2.7	0	0	0	0	47	12.9	1	.3	365	4.57	1.76	38.5
		Arrival at packing house..........	104	28.5	155	42.5	8	2.2	0	0	2	.5	77	21.1	19	5.2	365	4.57	2.04	44.7
Do.....	231, dirty fertile...	On arrival in town..................	74	33.9	120	55.1	8	3.7	1	.5	0	0	14	6.4	1	.5	218	2.73	.84	30.8
		Before leaving town..............	48	22.1	124	57.2	7	3.2	1	.5	0	0	36	16.6	1	.5	217	2.72	1.14	41.9
		Arrival at packing house..........	59	27.2	91	41.9	8	3.8	0	0	0	0	51	23.5	8	3.8	217	2.72	1.24	45.6
Do.....	385, clean infertile.	On arrival in town..................	240	64.4	116	31.1	17	4.6	0	0	0	0	0	0	0	0	373	4.66	.66	14.2
		Before leaving town..............	200	53.9	154	41.5	17	4.6	0	0	0	0	0	0	0	0	371	4.64	.86	18.5
		Arrival at packing house..........	162	43.8	178	48.1	21	5.7	0	0	2	.5	7	1.9	0	0	370	4.62	1.10	23.8

NOTE.—A comparison of the figures under column headed "Total eggs and condition" with those under column "Total eggs candled" will often show a variation. This variation is due to eggs becoming broken or lost.

G. THE STRAW-STACK EXPERIMENT.

From the results of this experiment, as set forth in Table 6, we may note the following points:

1. The difference in loss between clean fertile and infertile is much less than that of any other experiment, which would indicate that the conditions of the straw-stack nest were of such a severe nature that the infertile eggs were unable to resist it as successfully as they did in the other cases. This point is well illustrated by the figures in the column headed "Rots," where it will be noted that fully 5 per cent of both classes of eggs were so designated when candled at the packing house. Further illustration is found in the fact that in both fertile and infertile eggs the number of spots was greater than that experienced under any other condition.

It may also be of interest to note that during the extremely hot week of July 1 to 8 eggs that had been in this experiment after being candled at the packing house were broken and the albumen found to be cooked so hard that it could be cut with a knife without running.

2. The clean fertile eggs contained 20 blood rings (see candling report at packing house) while in the infertiles none were present, thereby making the total loss greater than in the infertile eggs.

3. Even under these severe conditions 24.8 per cent of the infertile eggs graded as firsts at the packing house, again demonstrating that this class of eggs is more resistant to bad conditions than any other. In concluding, we may say that this experiment gave the greatest number of spots and rots in infertile eggs.

TABLE 6.—*Condensed report of seven-day experiments with eggs placed in straw-stack nest.*

Time.	Total eggs and condition.	When candled.	Results of candling.														Total eggs candled.	Original value of eggs at 15 cents per dozen.	Loss.	
			Firsts.		Seconds.		Cracked.		Leakers.		Spots.		Blood rings.		Rots.					
			No.	*P. ct.*	*No.*	*P. ct.*	*No.*	*P. ct.*	*No.*	*P. ct.*	*No.*	*P. ct.*	*No.*	*P. ct.*	*No.*	*P. ct.*		*Dolls.*	*Dolls.*	*P. ct.*
June 10 to Aug. 26.	385, clean fertile...	On arrival in town................	52	13.8	296	78.8	10	2.7	0	0	14	3.7	4	1.1	0	0	376	4.70	1.76	37.5
		Before leaving town................	35	9.3	306	81.6	12	3.2	0	0	11	2.9	9	2.4	2	.5	375	4.69	1.86	39.8
		Arrival at packing house..........	50	13.5	253	68.2	17	4.6	0	0	12	3.2	20	5.4	19	5.1	371	4.64	1.99	42.9
Do.....	385, clean infertile.	On arrival in town................	108	29.1	226	60.9	10	2.7	0	0	23	6.2	0	0	4	1.1	371	4.64	1.52	32.8
		Before leaving town................	86	23.6	230	63.1	12	3.3	0	0	32	8.8	0	0	4	1.1	364	4.55	1.66	36.5
		Arrival at packing house..........	90	24.8	230	63.4	16	4.4	0	0	8	2.2	0	0	19	5.2	363	4.54	1.57	34.6

NOTE.—A comparison of the figures under the column headed "Total eggs and condition" with those under the column "Total eggs candled" will often show a variation. This variation is due to eggs becoming broken or lost.

H. THE STOLEN-NEST EXPERIMENTS.

Before discussing the results of these tests, as set forth in Tables 7, 8, and 9, it will be well to state that whenever two or more hens would lay in a nest on the same day all but one of the eggs laid were removed. This was done to keep the factor constant and not varying from day to day.

That there is a great difference in the quality of fertile eggs taken from a stolen nest just previous to the time the hen starts to sit is well brought out in Tables 7 and 8. In Table 7 it will be noted that 9 out of the 10 eggs were graded as seconds and the remaining 1 as a first, while in Table 8 there are 9 blood rings and 2 seconds. The only logical reason that can be set forth as the probable cause of such a variation is that the hen responsible for the eggs in nest 2 was inclined to sit on the eggs for a longer period each day during the time she was accumulating the nest of eggs than was the hen of nest 1. The fact that both experiments were conducted on practically the same days of the month makes the weather conditions identical in each case and eliminates the possibility of variations in temperature being responsible for the increased deterioration of the eggs in the latter nest. In both cases it was accurately determined, by breaking the eggs directly after candling, that those candled as seconds were fertile, since they showed similar development to that shown in Plate III, figure 3. The development had, of course, proceeded further in some instances than in others, but in every case it was of sufficient prominence to positively identify the egg as fertile.

Turning to Table 9, which is a condensed report of the detailed records of the 12 stolen nests, we may note (1) that out of the total of 88 eggs only 7.9 per cent could be classed as firsts when removed from the nest; (2) that slightly over one-half of the number had developed into seconds, 38.6 per cent being a total loss, and (3) that there was a total money loss of 60 per cent of the original value of the eggs. Such results as these, when we consider that the eggs had not been set upon steadily, as is the case in many nests of eggs which are found on the farm, are sufficiently convincing to prove that the eggs procured from such sources can easily be responsible for a part of the great loss now borne by the producer.

TABLE 7.—*Record of stolen nest No. 1, located in weeds.*

Dates visited.	Number of hens laying in nest.	Hen sitting.	Weather conditions.				Date candled.	Grade of egg.
			Rain.	Sky.	Temperature.			
					Max.	Min.		
			Inches.		*°F.*	*°F.*		
May 12	1	No	0.00	Clear	87	44	May 24	Second.
May 13	1	No	T.[1]	Pt. cl[2]	87	57	...do...	Do.
May 14	1	No	.22	...do...	84	65	...do...	Do.
May 15	2	No	.00	...do...	81	52	...do...	Do.
May 16	1	No	.00	...do...	90	65	...do...	Do.
May 17	1	No	.00	Clear	91	64	...do...	Do.
May 18	2	No	.00	Pt. cl.	93	72	...do...	Do.
May 19	3	No	.00	...do...	89	70	...do...	Do.
May 20	1	No	.00	...do...	75	52	...do...	Do.
May 21	0	No	.58	...do...	66	50	...do...	
May 22	1	No	.00	...do...	61	41	...do...	First.
May 23	0	Yes	.00	Clear	85	62	...do...	

[1] Trace.

[2] Part cloudy.

NOTE.—Second showed 24-hour development.

TABLE 8.—*Record of stolen nest No. 2, located in woodpile.*

Dates visited.	Number of hens laying in nest.	Hen sitting.	Weather conditions.				Date candled.	Grade of egg.
			Rain.	Sky.	Temperature.			
					Max.	Min.		
			Inches.		*°F.*	*°F.*		
May 12	1	No	0.00	Clear	87	44	May 26	Blood ring
May 13	1	No	T.[1]	Pt. cl.[2]	87	57	...do...	Do.
May 14	1	No	.22	...do...	84	65	...do...	Do.
May 15	0	No	.00	...do...	81	52	...do...	
May 16	1	No	.00	...do...	90	65	...do...	Do.
May 17	1	No	.00	Clear	91	64	...do...	Do.
May 18	1	No	.00	Pt. cl.[2]	93	72	...do...	Do.
May 19	1	No	.00	...do...	89	70	...do...	Do.
May 20	0	No	.00	...do...	75	52	...do...	
May 21	1	No	.58	...do...	66	50	...do...	Second.
May 22	1	No	.00	...do...	61	41	...do...	Blood ring.
May 23	1	No	.00	Clear	85	62	...do...	Do.
May 24	0	No	.00	...do...	96	55	...do...	
May 25	1	No	.00	...do...	95	67	...do...	Second.
May 26	0	Yes	.00	...do...	94	69	...do...	

[1] Trace.

[2] Part cloudy.

NOTE.—Second showed 24-hour development.

TABLE 9.—*Condensed report of stolen nests.*

Total number of nests.	Total eggs.	Results of candling.								Original value of eggs at 15 cents per dozen.	Loss.	
		Firsts.		Seconds.		Blood rings.		Rots.				
		Number.	*Per cent.*	*Number.*	*Per cent.*	*Number.*	*Per cent.*	*Number.*	*Per cent.*	*Dollars.*	*Dollars.*	*Per ct.*
12	88	7	7.9	47	53.4	27	30.7	7	7.9	1.10	0.66	60

COMPARISON OF CLEAN FERTILE EGGS UNDER SEVEN DIFFERENT CONDITIONS.

We have already discussed the results of the seven different experiments incorporated in Table 10, and it will now be of interest to compare collectively the total number of clean fertile eggs in each of them. Before doing so, however, it is well to call attention to the fact that the date in the table on which the tests with clean fertile eggs began is with one exception given as April 24, while in the condensed tables referring to the separate experiments it is given in some instances as June 10 and in others as June 17. This apparent contradiction is owing to the fact that the tests with infertile eggs did not start until the latter dates, and if we are to compare the results of experiments with these two classes of eggs, it is obvious that the work in each case must start and end on identical dates.

From the data in Table 10 the following points will be noted:

1. A comparison of the number and per cent of blood rings and rots which were present in the eggs of the different experiments when candled at the packing house will show that those kept in the cave were the only ones that did not suffer a heavy loss through these two grades. In the cave eggs the loss from this source was only 0.5 per cent, while in the remaining experiments it varies from 8.8 per cent for straw stack to 55.1 per cent in nests for layers.
2. The conditions in the straw-stack experiment gave rise to the greatest number of spots. By referring to Table 11, it can be seen that this also held good in the case of infertile eggs.
3. By comparing the total per cent of loss of each experiment it will be seen at a glance that the irregular gathering of the eggs (nests for layers test) was the cause of the greatest loss both at the farm and packing house. On the other hand one can see immediately that, excepting the cave experiment, the various conditions under which the tests were made are responsible for a large part of the bad eggs which we find on the market to-day.
4. In all experiments except the cave the total depreciation in the quality of clean fertile eggs is of enough importance to justify the statement that high-quality eggs can not be produced under any of these conditions. The best place to keep eggs, other than the cave, was found in the parlor of the dwelling house, and even here we note a total loss of one-third of the value of the eggs when candled at the packing house. This result must obviously eliminate such a location as a suitable place to keep fertile eggs during the warm weather, which leaves the cave or dry, cool cellar as the only alternative.

TABLE 10.—*Comparison of clean fertile eggs under seven different conditions.*

Time.	Total eggs and condition.	When candled.	Results of candling.														Total eggs candled.	Original value of eggs at 15 cents per dozen.	Loss.	
			Firsts.		Seconds.		Cracked.		Leakers.		Spots.		Blood rings.		Rots.					
			No.	*P. ct.*	*No.*	*P. ct.*	*No.*	*P. ct.*	*No.*	*P. ct.*	*No.*	*P. ct.*	*No.*	*P. ct.*	*No.*	*P. ct.*		*Dollars.*	*Dollars.*	*Per ct.*
Apr. 24 to Aug. 26.	641 clean fertile eggs in cave.	On arrival in town	588	92.8	31	4.9	15	2.4	0	0	0	0	0	0	0	0	634	7.92	0.23	2.9
		Before leaving town	538	85.0	80	12.6	15	2.4	0	0	0	0	0	0	0	0	633	7.91	.47	5.5
		Arrival at packing house	420	66.8	177	28.2	27	4.3	0	0	2	.3	3	.5	0	0	629	7.86	1.08	13.9
Do.	653 clean fertile eggs in parlor of dwelling house.	On arrival in town	407	62.9	203	31.4	7	1.1	0	0	0	0	30	4.6	0	0	647	8.09	1.43	17.8
		Before leaving town	328	51.0	247	38.3	11	1.7	0	0	0	0	57	8.9	1	.2	644	8.05	2.01	25.7
		Arrival at packing house	267	41.7	261	40.8	15	2.3	0	0	1	.2	56	8.8	40	6.3	640	8.00	2.59	32.0
Do.	653 clean fertile eggs under corncrib.	On arrival in town	351	55.2	251	39.4	7	1.1	0	0	0	0	27	4.3	0	0	636	7.95	1.63	20.4
		Before leaving town	233	36.9	335	53.0	9	1.4	0	0	0	0	54	8.5	1	.2	632	7.90	2.41	30.5
		Arrival at packing house	247	39.3	267	42.5	11	1.8	0	0	3	.5	71	11.3	30	4.8	629	7.86	2.69	34.3
Do.	653 clean fertile eggs in weed nest.	On arrival in town	324	52.1	270	43.4	13	2.1	0	0	0	0	14	2.3	1	.2	622	7.77	1.60	20.6
		Before leaving town	247	40.2	299	48.6	20	3.3	0	0	0	0	47	7.6	2	.3	615	7.69	2.20	28.6
		Arrival at packing house	233	38.0	257	42.0	18	2.9	0	0	2	.3	83	13.6	20	3.3	613	7.66	2.68	35.0
Do.	653 clean fertile eggs in straw stack.	On arrival in town	227	35.4	377	58.8	17	2.7	0	0	14	2.2	4	.6	2	.3	641	8.01	2.22	27.7
		Before leaving town	178	28.0	414	65.2	19	3.0	0	0	11	1.7	9	1.4	4	.6	635	7.94	2.46	31.0
		Arrival at packing house	173	27.5	362	57.6	26	4.1	0	0	12	1.9	32	5.1	23	3.7	628	7.85	2.78	35.4
Do.	646 clean fertile eggs in nests for layers (sitters present).	On arrival in town	135	21.3	304	48.0	7	1.2	0	0	0	0	158	25.0	29	4.6	633	7.91	3.89	49.1
		Before leaving town	113	17.9	272	43.1	12	1.9	0	0	1	.2	182	28.9	50	7.9	630	7.88	4.33	55.0
		Arrival at packing house	103	16.4	239	38.0	9	1.4	1	.2	7	1.1	155	24.6	115	18.3	629	7.86	4.71	60.0
Do.	479 clean fertile eggs in nests for layers (no sitters).	On arrival in town	60	13.2	210	46.1	10	2.2	0	0	0	0	142	31.2	34	7.5	456	5.70	3.30	58.0
		Before leaving town	33	7.2	195	42.8	11	2.4	0	0	0	0	165	36.2	52	11.4	456	5.70	3.74	65.6
		Arrival at packing house	31	6.8	164	36.2	5	1.1	1	.2	3	.7	127	28	123	27.1	454	5.67	4.01	70.8

NOTE.—A comparison of the figures under column headed "Total eggs and condition" with those under column "Total eggs candled" will often show a variation. The variation is due to eggs being broken or lost.

COMPARISON OF CLEAN INFERTILE EGGS UNDER SIX DIFFERENT CONDITIONS.

It may be noted from the data given in Table 11 concerning the clean infertile eggs in the various experiments: First, that eggs held in the cave gave the highest percentage of firsts at the farm and packing house, and that the eggs kept in the parlor of the dwelling house were second best. Second, instead of the greatest deterioration occurring in the eggs placed in the nests for layers, as was the case with fertile eggs, we find that those of the straw stack suffered the heaviest loss. Third, that the straw-stack condition was the most conducive to the production of spots and rots in infertile eggs. Fourth, excepting the cyclone cave, the final losses under all the other different conditions plainly show that they are not conducive to good quality in eggs. With the exception of the house experiment such results would naturally be expected.

TABLE 11.—*Comparison of clean infertile eggs under six different conditions.*

Time.	Total eggs and condition.	When candled.	Results of candling.														Total eggs candled.	Original value of eggs at 15 cents per dozen.	Loss.	
			Firsts.		Seconds.		Cracked.		Leakers.		Spots.		Blood rings.		Rots.					
			No.	*P. ct.*	*No.*	*P. ct.*	*No.*	*P. ct.*	*No.*	*P. ct.*	*No.*	*P. ct.*	*No.*	*P. ct.*	*No.*	*P. ct.*		*Dollars.*	*Dollars.*	*Per ct.*
June 10 to Aug. 26.	385 clean infertile eggs in cave.	On arrival in town	375	97.4	4	1.0	6	1.6	0	0	0	0	0	0	0	0	385	4.81	0.05	1.0
		Before leaving town	369	95.9	10	2.6	6	1.6	0	0	0	0	0	0	0	0	385	4.81	.08	1.7
		Arrival at packing house	264	68.6	111	28.8	10	2.6	0	0	0	0	0	0	0	0	385	4.81	.60	12.5
Do.	350 clean infertile eggs in parlor of dwelling house.	On arrival in town	246	70.5	94	26.9	8	2.3	1	.3	0	0	0	0	0	0	349	4.36	.52	11.9
		Before leaving town	199	57.6	138	39.9	9	2.6	0	0	0	0	0	0	0	0	346	4.32	.74	17.1
		Arrival at packing house	164	47.4	171	49.4	9	2.6	0	0	1	.3	1	.3	0	0	346	4.32	.92	21.3
Do.	385 clean infertile eggs under corncrib.	On arrival in town	266	70.2	108	28.5	5	1.3	0	0	0	0	0	0	0	0	379	4.74	.56	11.8
		Before leaving town	206	54.6	163	43.2	7	1.9	0	0	0	0	1	.3	0	0	377	4.71	.86	21.0
		Arrival at packing house	172	45.6	186	49.3	10	2.7	0	0	1	.3	6	1.6	2	.5	377	4.71	1.09	23.2
Do.	385 clean infertile eggs in weed nest.	On arrival in town	240	64.4	116	31.1	17	4.6	0	0	0	0	0	0	0	0	373	4.66	.66	14.2
		Before leaving town	200	53.9	154	41.5	17	4.6	0	0	0	0	0	0	0	0	371	4.64	.86	18.5
		Arrival at packing house	162	43.8	178	48.1	21	5.7	0	0	2	.5	7	1.9	0	0	370	4.62	1.10	23.8
Do.	385 clean infertile eggs in straw stack.	On arrival in town	108	29.1	226	60.9	10	2.7	0	0	23	6.2	0	0	4	1.1	371	4.64	1.52	32.8
		Before leaving town	86	23.6	230	63.1	12	3.3	0	0	32	8.8	0	0	4	1.1	364	4.55	1.66	36.5
		Arrival at packing house	90	24.8	230	63.4	16	4.4	0	0	8	2.2	0	0	19	5.2	363	4.54	1.57	34.6
Do.	385 clean infertile eggs in nests for layers (sitters present).	On arrival in town	192	50.8	164	43.4	12	3.2	0	0	0	0	8	2.1	2	.5	378	4.73	1.00	21.1
		Before leaving town	155	41.0	196	51.8	12	3.2	1	.3	0	0	11	2.9	3	.8	378	4.73	1.23	26.0
		Arrival at packing house	120	32.0	223	59.5	14	3.7	0	0	0	0	13	3.5	5	1.3	375	4.69	1.42	30.3

NOTE.—A comparison of the figures under column headed "Total eggs and condition" with those under column "Total eggs candled" will often show a variation. The variation is due to eggs being broken or lost.

A COMPARISON OF THE LOSSES IN CLEAN FERTILE AND INFERTILE EGGS UNDER ALL THE EXPERIMENTAL CONDITIONS.

From the data in Table 12 and the graphic representation in text figure 1 we note:

1. That in all three candlings the loss in fertile eggs is nearly twice that of the infertile. This point is of the utmost importance to the producer, since it demonstrates beyond a doubt that by removing the male birds as soon as the hatching season is over, which should be about the middle of May, the quality and value of the subsequent eggs, regardless of where they are kept, is increased very materially.

2. The increased loss in fertile eggs is due mainly to the development of blood rings and rots, which, as has been shown in the previous discussion, can easily occur even when the eggs receive good care on the farm. The fact that they are fertile makes them subject to rapid deterioration of such a nature as to render them unfit for consumption.

3. By referring to figure 1 it will be seen that practically two-thirds of the total loss in fertile and infertile eggs occurred on the farm, the remaining loss taking place in town and during transportation from town to packing house. It is highly probable that if the eggs had all been firsts when leaving the farm the above loss would have been materially lessened. The important point to be brought out, however, is that the haphazard methods followed in the production and care of eggs on the farm are the principal factors which must be eliminated if the quality of the commercial egg is to be improved. True, there is room for improvement in the methods of handling and transportation after the egg leaves the farm, but, as brought out in Table 1 (p. 22), the only depreciation occurring during transit in clean infertile eggs kept in the cyclone cave was a slight shrink in the contents of a part of them, thereby making it necessary to class them as seconds.

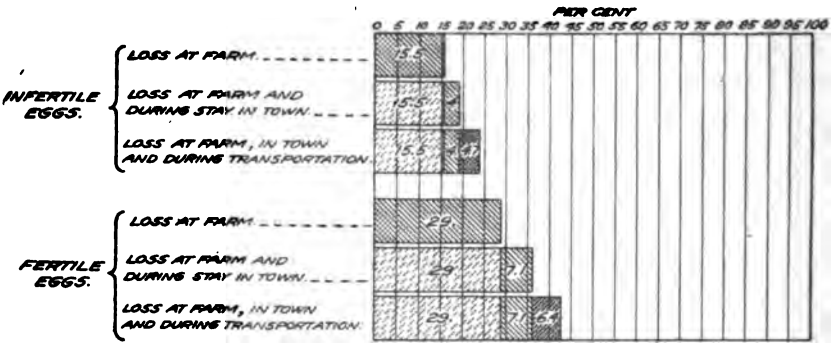

FIG. 1.—Showing per cent of loss in fertile and infertile eggs from farm to market. (See Table 12.)

TABLE 12.—*Condensed report showing loss in clean fertile and infertile eggs for entire season under all experimental conditions.*

Class of eggs.	Time.	When candled.	Results of candling.														Total eggs candled.	Original value of eggs, at 15 cents per dozen.	Loss.	
			Firsts.		Seconds.		Cracked.		Leakers.		Spots.		Blood rings.		Rots.					
			Number.	*Per cent.*	*Number.*	*Per cent.*	*Number.*	*Per cent.*	*Number.*	*Per cent.*	*Number.*	*Per cent.*	*Number.*	*Per cent.*	*Number.*	*Per cent.*		*Dollars.*	*Dollars.*	*Per cent.*
Fertile	June 10 to Aug. 26.	On arrival in town	916	40.6	1,106	49.0	39	1.7	0	0	14	0.6	167	7.4	15	0.7	2,257	28.21	8.17	29.0
Infertile	do	do	1,427	63.8	712	31.9	58	2.6	1	.0+	23	1.0	8	.4	6	.3	2,235	27.94	4.32	15.5
Fertile	do	Before leaving town	688	30.5	1,197	53.1	56	2.5	0	0	11	.5	273	12.1	29	1.3	2,254	28.17	10.17	36.1
Infertile	do	do	1,215	54.7	891	40.3	63	2.8	1	.0+	32	1.4	12	.5	7	.3	2,221	27.76	5.42	19.5
Fertile	do	On arrival at packing house.	614	27.3	1,063	47.4	64	2.9	1	.0+	22	1.0	298	13.3	183	8.2	2,245	28.06	11.93	42.5
Infertile	do	do	972	44.0	1,099	49.6	80	3.6	0	0	12	.5	27	1.2	26	1.2	2,216	27.70	6.71	24.2

RELATION OF TEMPERATURE TO DETERIORATION IN EGGS.

In the condensed reports of the different experiments it has only been possible to note the total depreciation for the season. Therefore it will be of interest to here note the deterioration in fertile and infertile eggs of various ages during moderately cool and extremely hot weather. Tables 13, 14, and 15 are detailed reports of 7-day experiments conducted in the parlor of the dwelling house, and the figures contained in them are the results of the first candling, which represents the loss at the farm. Figures 2 and 3 are thermograph reports of the temperature and humidity of the room during the time the above tests were made. The experiments started and ended on Saturday, as will be noted by referring to the thermograph records, where it will be seen that directly under Saturday there is a break in the line representing the temperature. This, of course, is occasioned by beginning and ending the record on the above day.

From figure 2, and the data in Table 13, which records the results of keeping fertile eggs in moderately cool weather, we note:

1. That the range of temperature for the seven days was between 63 and 88° F. 2. When subjected to the above range of temperature there was no loss in fertile eggs from one to six days old. 3. That in fertile eggs seven days old one out of six had deteriorated so as to become a second, which meant a decrease in quality of 16.7 per cent. The actual money loss, however, resulting from the above shrinkage in quality is but one-half a cent, which is not serious enough to be of significance. 4. That fresh fertile eggs placed in an unheated room of the dwelling house, the maximum daily temperature of which is 88° F., or under, will, if marketed frequently, be in sufficiently good condition to grade as firsts or full fresh eggs. There is a possibility that they would be in good condition at the expiration of seven days, but it is wiser to dispose of them at least twice a week.

Turning to Tables 14 and 15, where is given the depreciation during extremely hot weather, we find that after 24 hours 40 per cent of the fertile and 20 per cent of the infertile eggs had developed into seconds. At the age of four days 40 per cent of the fertile eggs are a total loss and on the fifth day 100 per cent. In the infertile eggs (Table 15) the rate of deterioration is not so great, but after the fourth day 100 per cent of the eggs are seconds. At the end of seven days the infertile eggs have a market value of 60 per cent of their original value, while the fertile eggs under the same conditions are a total loss.

The conclusions which may be drawn from the results of these three experiments are: First, that the quality of fertile and infertile eggs retained in a room of the dwelling house does not change to any appreciable extent during a period of from four to five days when the maximum temperature is 88° F., or under. Second, during extremely hot weather, when the daily maximum temperature is 100° F., or over, both fertile and infertile eggs start to deteriorate during the first 24 hours. The depreciation in fertiles is so rapid that after the fourth day they are a total loss, while in the infertiles, owing to the absence of fertilization, the loss is much less.

TABLE 13.—*Deterioration in fertile eggs kept in dwelling house during moderately cool weather.*

Number of eggs.	Age.	Results of candling.													
		Firsts.		Seconds.		Cracked.		Leakers.		Spots.		Blood rings.		Rots.	
	Days.	*No.*	*P. ct.*	*No.*	*P. ct.*	*No.*	*P. ct.*	*No.*	*P. ct.*	*No.*	*P. ct.*	*No.*	*P. ct.*	*No.*	*P. ct.*
6.......	1	6	100.0	0	0	0	0	0	0	0	0	0	0	0	0
6.......	2	6	100.0	0	0	0	0	0	0	0	0	0	0	0	0
6.......	3	6	100.0	0	0	0	0	0	0	0	0	0	0	0	0
6.......	4	6	100.0	0	0	0	0	0	0	0	0	0	0	0	0
6.......	5	6	100.0	0	0	0	0	0	0	0	0	0	0	0	0
6.......	6	6	100.0	0	0	0	0	0	0	0	0	0	0	0	0
6.......	7	5	83.3	1	16.7	0	0	0	0	0	0	0	0	0	0
Total.42	......	41	97.6	1	2.4	0	0	0	0	0	0	0	0	0	0

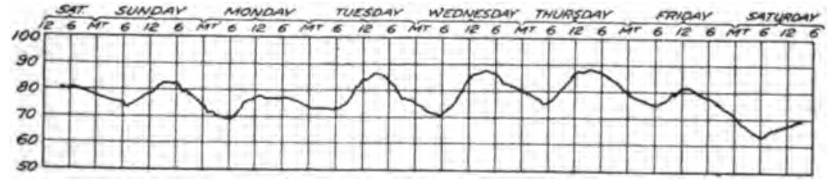

FIG. 2.—Thermograph record showing temperature in parlor of dwelling house during one week of moderately cool weather.

TABLE 14.—*Deterioration in fertile eggs kept in dwelling house during very hot weather.*

Number of eggs.	Age.	Results of candling.													
		Firsts.		Seconds.		Cracked.		Leakers.		Spots.		Blood rings.		Rots.	
	Days.	*No.*	*P. ct.*	*No.*	*P. ct.*	*No.*	*P. ct.*	*No.*	*P. ct.*	*No.*	*P. ct.*	*No.*	*P. ct.*	*No.*	*P. ct.*
5.......	1	3	60.0	2	40.0	0	0	0	0	0	0	0	0	0	0
5.......	2	2	40.0	3	60.0	0	0	0	0	0	0	0	0	0	0
5.......	3	0	0	5	100.0	0	0	0	0	0	0	0	0	0	0
5.......	4	0	0	3	60.0	0	0	0	0	0	0	2	40.0	0	0
5.......	5	0	0	0	0	0	0	0	0	0	0	5	100.0	0	0
5.......	6	0	0	0	0	0	0	0	0	0	0	5	100.0	0	0
5.......	7	0	0	0	0	0	0	0	0	0	0	5	100.0	0	0
Total.35	......	5	14.3	13	37.2	0	0	0	0	0	0	17	48.5	0	0

Table 15.—*Deterioration in infertile eggs kept in dwelling house during very hot weather.*

Number of eggs.	Age.	Results of candling.													
		Firsts.		Seconds.		Cracked.		Leakers.		Spots.		Blood rings.		Rots.	
	Days.	*No.*	*P.ct.*	*No.*	*P.ct.*	*No.*	*P.ct.*	*No.*	*P.ct.*	*No.*	*P.ct.*	*No.*	*P.ct.*	*No.*	*P.ct.*
5.......	1	4	80.0	1	20.0	0	0	0	0	0	0	0	0	0	0
5.......	2	5	100.0	0	0	0	0	0	0	0	0	0	0	0	0
5.......	3	4	80.0	1	20.0	0	0	0	0	0	0	0	0	0	0
5.......	4	2	40.0	3	60.0	0	0	0	0	0	0	0	0	0	0
5.......	5	0	0	5	100.0	0	0	0	0	0	0	0	0	0	0
5.......	6	0	0	5	100.0	0	0	0	0	0	0	0	0	0	0
5.......	7	0	0	5	100.0	0	0	0	0	0	0	0	0	0	0
Total.35	......	15	42.9	20	57.2	0	0	0	0	0	0	0	0	0	0

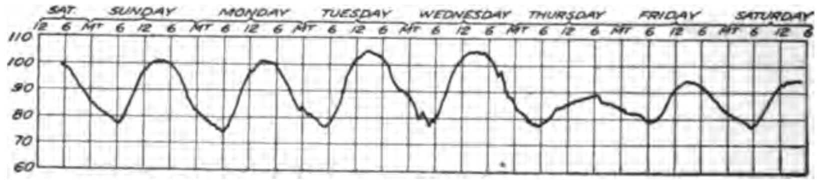

FIG. 3.—Thermograph record showing temperature in parlor of dwelling house for one week during hot weather.

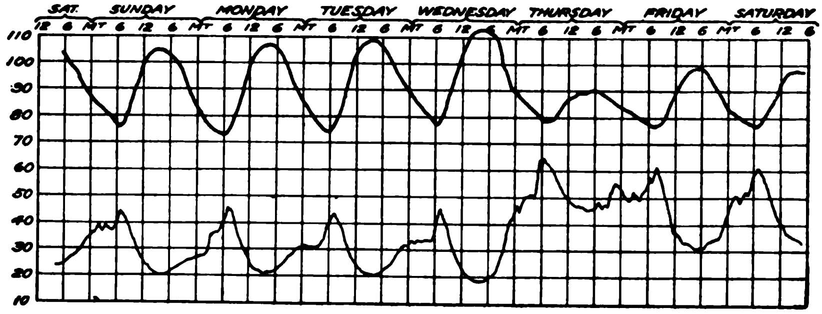

FIG. 4.—Temperature and humidity records for week of July 1 to 8, 1911. Upper line represents temperature; lower represents humidity. On Wednesday, July 5, it will be noticed, the temperature needle was forced off the recording sheet, as it is designed to record temperature up to 110° F. only. The thermometer registered a temperature of 114° F. on this day.

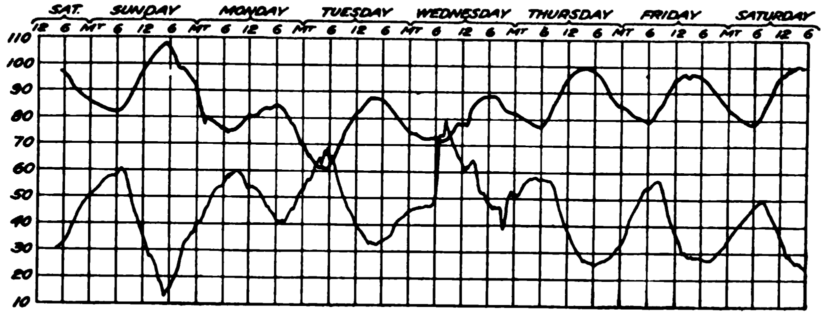

FIG. 5.—Temperature and humidity records taken from thermograph used in the house experiments for week June 24 to July 1, 1911. Upper line represents temperature; lower, humidity.

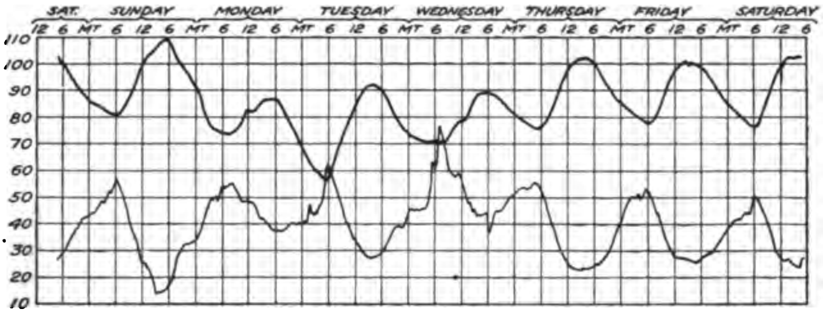

FIG. 6—Temperature and humidity records taken from thermograph used in outside experiments for week June 24 to July 1, 1911. Upper line represents temperature; lower, humidity.

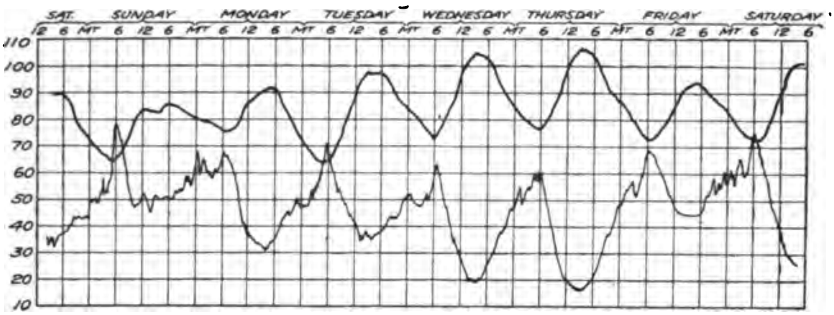

FIG. 7.—Temperature and humidity records from August 5 to 12, 1911. Upper line represents temperature; lower, humidity.

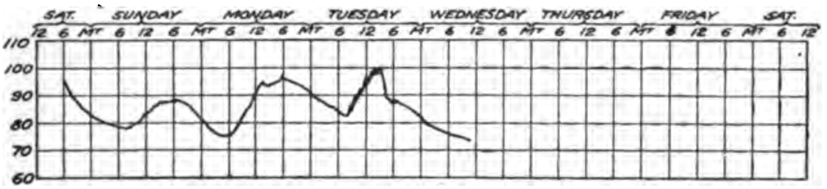

FIG. 8.—Thermograph record showing temperatures and length of time eggs were held in town, on train while standing, and in transit. The record begins at 6 p. m. Saturday, July 1, and ends at 10 a. m. Wednesday, July 5. The blotted line shows when the train was in motion, and the light smooth line that the eggs were held in the country store from 6 o'clock Saturday, July 1, until about 10 o'clock Monday, July 3, 1911. Eggs and thermograph were in open stock car. Note high temperature at 2 o clock Tuesday, July 4.

SUMMARY.

This paper constitutes a general study from a practical standpoint of the deterioration occurring in the various classes of fertile and infertile eggs when kept on the farm under different environmental conditions. The data on which this study is based are the results of extensive experimental egg work carried on in the State of Kansas. The chief results of these tests are summarized in the following paragraphs:

1. Eggs kept in the cyclone cave proved much better in quality than those kept under other conditions.

2. Taking the season as a whole, an unheated room in a dwelling house is not conducive to good quality in eggs.

3. During the hot summer months the conditions surrounding the weed nest, the nest in the straw stack, or under the corncrib, and the stolen nest, as well as the keeping of eggs in the house, favor the production of spots, blood rings, and rots.

4. The greatest deterioration in fertile eggs occurred in the experiments which included a certain amount of natural incubation, namely, in the nests for layers and the stolen-nest experiments.

5. The straw-stack experiment gave the greatest number of spots, both in fertile and infertile eggs, and also the highest percentage of rots in the latter class of eggs. It was the only test in which a large number of infertile eggs deteriorated to such an extent as to be unfit for food.

6. In fertile eggs the development of the embryo after 24 hours of incubation was of sufficient proportion to be recognized when held before the candle, and at the expiration of 36 hours the presence of blood was easily detected. In infertile eggs under the same conditions a slight shrinkage of the contents was the only change which could be recognized by the eye.

7. Infertile eggs, regardless of where they may be kept, are much more resistant to deterioration than fertile.

8. Two-thirds of the total loss in fertile and infertile eggs takes place on the farm. The basic factors responsible for this condition are the haphazard methods of poultry management on the farm.

9. If eggs are fresh when delivered to the buyer it is impossible, with the present methods of transportation, for them to reach the packing house without showing a slight deterioration in quality. The data at hand (see Table 1) would indicate that this loss is about 12 per cent of the original value of the eggs.

10. The results of all the experimental work point to the fact that the production of the infertile egg is the greatest asset in the attempt to produce high-quality market eggs during hot weather.

11. The authors believe that if the five simple rules given below are followed by egg producers generally a high quality of product will be assured and a very large part prevented of the loss now experienced in the value of the country's egg production:

Give the hens clean nests.
Gather eggs at least once daily.
Keep eggs in a cool, dry place.
Market eggs at least twice a week.
Kill or sell all mature male birds as soon as the hatching season closes.

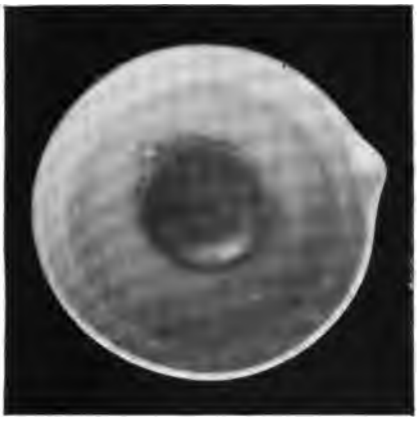

FIG. 1.—NORMAL FRESH EGG.

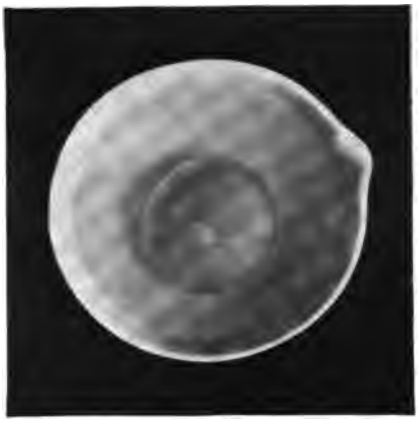

FIG. 2.—FRESH EGG SHOWING BLOOD CLOT.

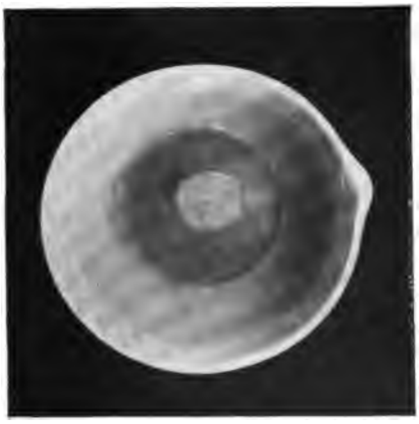

FIG. 3.—FERTILE EGG AFTER 24 HOURS OF INCUBATION.

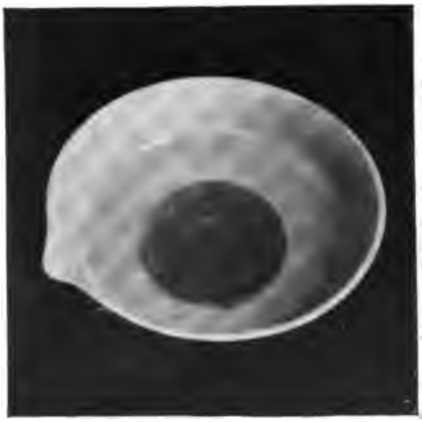

FIG. 4.—INFERTILE EGG AFTER 24 HOURS OF INCUBATION.

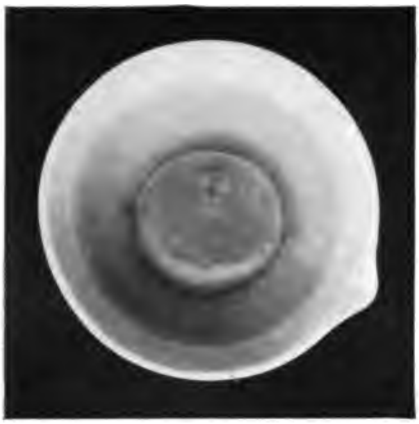

FIG. 1.—FERTILE EGG ALLOWED TO DIE AFTER 36 HOURS OF INCUBATION.

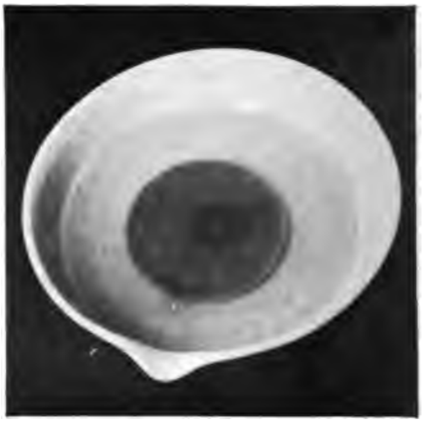

FIG. 2.—INFERTILE EGG AFTER 36 HOURS OF INCUBATION.

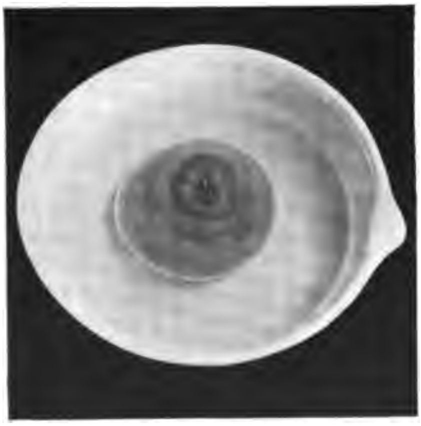

FIG. 3.—FERTILE EGG AFTER 48 HOURS OF INCUBATION.

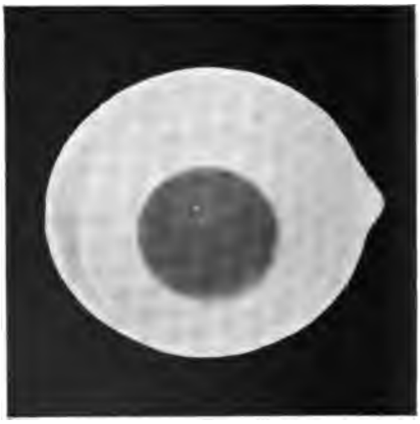

FIG. 4.—INFERTILE EGG AFTER 48 HOURS OF INCUBATION.

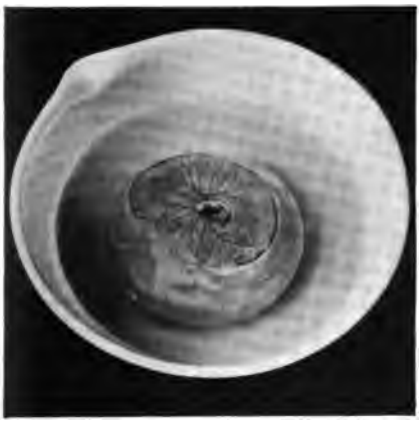

FIG. 1.—FERTILE EGG AFTER 72 HOURS OF INCUBATION.

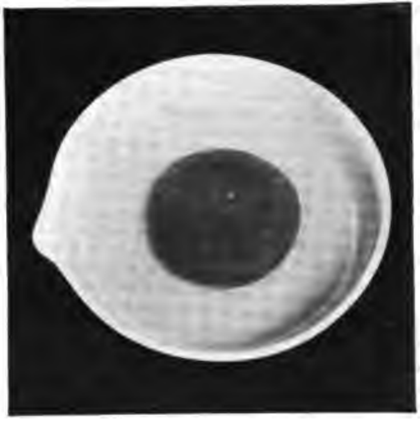

FIG. 2.—INFERTILE EGG AFTER 72 HOURS OF INCUBATION.

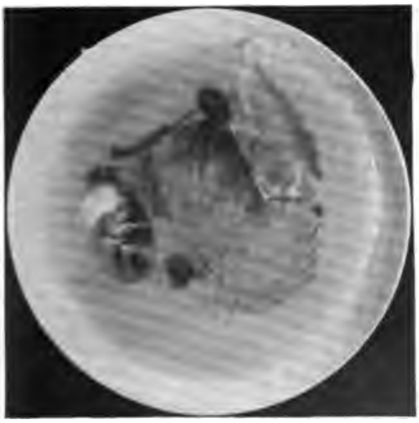

FIG. 3.—FERTILE EGG AFTER 7 DAYS OF INCUBATION.

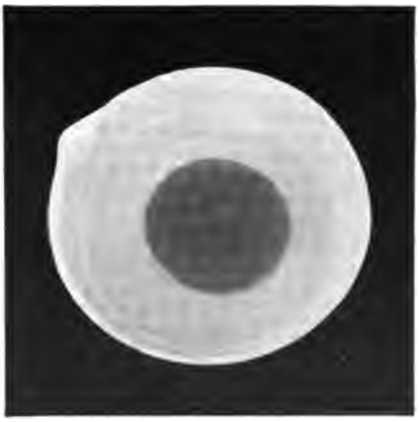

FIG. 4.—INFERTILE EGG AFTER 7 DAYS OF INCUBATION.

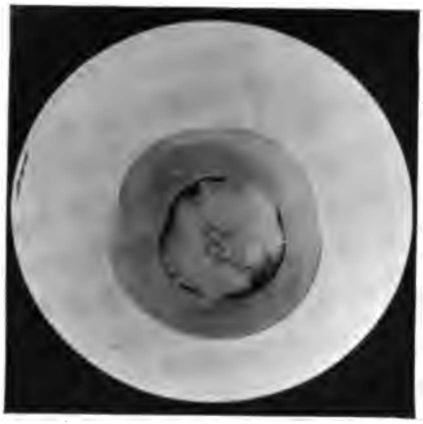

FIG. 1.—FERTILE EGG ALLOWED TO DIE AFTER 72 HOURS OF INCUBATION.

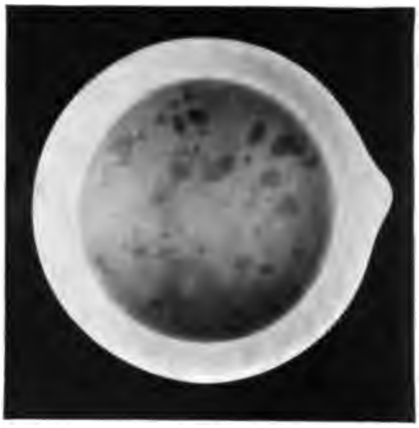

FIG. 2.—MIXED ROT.

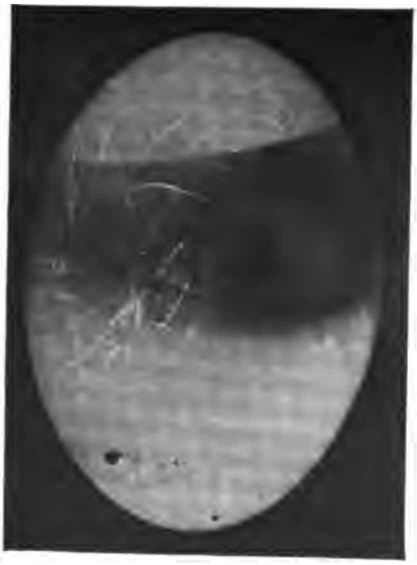

FIG. 3.—EGG SHOWING MOLD SPOT.

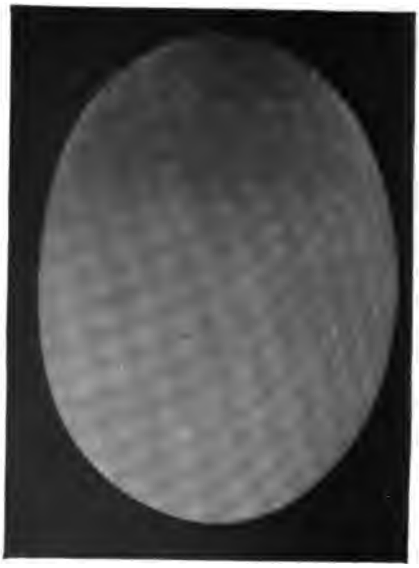

FIG. 4.—EGG SHOWING PLAIN SPOT.

APPENDIX.

As a sample of the way in which the complete data of the various experiments in this bulletin were placed on record, we append the details of the cyclone-cave experiment as carried out throughout the season, from April 24 to August 26, 1911. A condensed report of this experiment has previously been given as Table 2, on page 25. It is considered unnecessary to publish the complete records of the other experiments.

Detailed record of the

Experiment No.	Kind of eggs.	Number used per day.	Total eggs.[1]	Length of experiment.	Weather and temperature.[2]	When candled.
1	Fertile	6	36	Apr. 24-30	Tables 1, 2	On arrival in town
						Before leaving town
						Arrival at packing house
20	do	6	36	Apr. 30-May 6.	Tables 1, 2, 6	On arrival in town
						Before leaving town
						Arrival at packing house
21	Washed fertile	3	18	do	do	On arrival in town
						Before leaving town
						Arrival at packing house
22	Dirty fertile	3	18	do	do	On arrival in town
						Before leaving town
						Arrival at packing house
40	Fertile	6	42	May 6-13	Tables 2, 7; record 7.	On arrival in town
						Before leaving town
						Arrival at packing house
41	Dirty fertile	3	21	do	do	On arrival in town
						Before leaving town
						Arrival at packing house
42	Washed fertile	3	21	do	do	On arrival in town
						Before leaving town
						Arrival at packing house
57	Fertile	6	42	May 13-20	Tables 2, 8; record 10.	On arrival in town
						Before leaving town
						Arrival at packing house
58	Dirty fertile	3	21	do	do	On arrival in town
						Before leaving town
						Arrival at packing house
59	Washed fertile	3	21	do	do	On arrival in town
						Before leaving town
						Arrival at packing house
63	Fertile	6	30	May 22-27	Tables 2, 9; record 13.	On arrival in town
						Before leaving town
						Arrival at packing house
64	Dirty fertile	3	15	do	do	On arrival in town
						Before leaving town
						Arrival at packing house
65	Washed fertile	3	15	do	do	On arrival in town
						Before leaving town
						Arrival at packing house
87	Infertile	5	35	May 27-June 3.	Tables 2, 3, 10; record 16.	On arrival in town
						Before leaving town
						Arrival at packing house
88	Washed infertile	3	21	do	do	On arrival in town
						Before leaving town
						Arrival at packing house
89	Dirty infertile	3	21	do	do	On arrival in town
						Before leaving town
						Arrival at packing house
90	Fertile	5	35	do	do	On arrival in town
						Before leaving town
						Arrival at packing house
91	Dirty fertile	3	21	do	do	On arrival in town
						Before leaving town
						Arrival at packing house
92	Washed fertile	3	21	do	do	On arrival in town
						Before leaving town
						Arrival at packing house
109	Infertile	5	35	June 3-10	Tables 3, 11; record 19.	On arrival in town
						Before leaving town
						Arrival at packing house
110	Dirty, infertile	3	21	do	do	On arrival in town
						Before leaving town
						Arrival at packing house
111	Washed, infertile	3	21	do	do	On arrival in town
						Before leaving town
						Arrival at packing house

---

[1] A comparison of the figures under column headed "Total eggs" with those under column "Total eggs candled" will often show a variation. This variation is due to eggs becoming broken or lost.

[2] The tables and records referred to in this column are not those in the present bulletin. They are part of the original data on file in connection with the complete records of these experiments.

[3] Five eggs broken.

cyclone-cave experiment.

Results of candling.														Total eggs candled.[1]	Total deterioration (per cent).	Remarks.
Firsts.		Seconds.		Cracked.		Leakers.		Spots.		Blood rings.		Rots.				
Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.			
36	100.0	0	0	0	0	0	0	0	0	0	0	0	0	36	0	
36	100.0	0	0	0	0	0	0	0	0	0	0	0	0	36	0	
33	91.7	2	5.6	1	2.8	0	0	0	0	0	0	0	0	36	8.3	
31	100.0	0	0	0	0	0	0	0	0	0	0	0	0	31	0	(4)
30	96.8	1	3.2	0	0	0	0	0	0	0	0	0	0	31	3.2	
25	80.6	5	16.1	1	3.2	0	0	0	0	0	0	0	0	31	19.4	
17	94.4	1	5.6	0	0	0	0	0	0	0	0	0	0	18	5.6	
16	88.9	2	11.1	0	0	0	0	0	0	0	0	0	0	18	11.1	
15	83.3	3	16.7	0	0	0	0	0	0	0	0	0	0	18	16.7	
16	94.1	1	5.9	0	0	0	0	0	0	0	0	0	0	17	5.9	(4)
16	94.1	1	5.9	0	0	0	0	0	0	0	0	0	0	17	5.9	
15	88.2	2	11.8	0	0	0	0	0	0	0	0	0	0	17	11.8	
41	100.0	0	0	0	0	0	0	0	0	0	0	0	0	41	0	(4)
41	100.0	0	0	0	0	0	0	0	0	0	0	0	0	41	0	
41	100.0	0	0	0	0	0	0	0	0	0	0	0	0	41	0	
19	95.0	1	5.0	0	0	0	0	0	0	0	0	0	0	20	5.0	(4)
19	95.0	1	5.0	0	0	0	0	0	0	0	0	0	0	20	5.0	
20	100.0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	
21	100.0	0	0	0	0	0	0	0	0	0	0	0	0	21	0	
21	100.0	0	0	0	0	0	0	0	0	0	0	0	0	21	0	
20	95.2	1	4.8	0	0	0	0	0	0	0	0	0	0	21	4.8	
40	95.2	1	2.4	1	2.4	0	0	0	0	0	0	0	0	42	4.8	
34	81.0	7	16.6	1	2.4	0	0	0	0	0	0	0	0	42	19.0	
37	88.1	3	7.1	2	4.8	0	0	0	0	0	0	0	0	42	11.9	
20	95.2	1	4.8	0	0	0	0	0	0	0	0	0	0	21	4.8	
16	76.2	4	19.0	1	4.8	0	0	0	0	0	0	0	0	21	23.8	
17	81.0	4	19.0	0	0	0	0	0	0	0	0	0	0	21	19.0	
20	95.2	1	4.8	0	0	0	0	0	0	0	0	0	0	21	4.8	
19	90.5	2	9.5	0	0	0	0	0	0	0	0	0	0	21	9.5	
18	90.0	1	5.0	1	5.0	0	0	0	0	0	0	0	0	20	10.0	(4)
30	100.0	0	0	0	0	0	0	0	0	0	0	0	0	30	0	(5)
30	100.0	0	0	0	0	0	0	0	0	0	0	0	0	30	0	
29	96.7	0	0	1	3.3	0	0	0	0	0	0	0	0	30	3.3	
14	93.3	0	0	1	6.7	0	0	0	0	0	0	0	0	15	6.7	
14	93.3	0	0	1	6.7	0	0	0	0	0	0	0	0	15	6.7	
14	100.0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	(4)
14	93.3	0	0	1	6.7	0	0	0	0	0	0	0	0	15	6.7	
14	93.3	0	0	1	6.7	0	0	0	0	0	0	0	0	15	6.7	
12	80.0	2	13.3	1	6.7	0	0	0	0	0	0	0	0	15	20.0	
34	97.1	0	0	1	2.9	0	0	0	0	0	0	0	0	35	2.9	
32	91.4	2	5.7	1	2.9	0	0	0	0	0	0	0	0	35	8.6	
31	88.6	4	11.4	0	0	0	0	0	0	0	0	0	0	35	11.4	
21	100.0	0	0	0	0	0	0	0	0	0	0	0	0	21	0	
21	100.0	0	0	0	0	0	0	0	0	0	0	0	0	21	0	
20	100.0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	(4)
20	95.2	1	4.8	0	0	0	0	0	0	0	0	0	0	21	4.8	
18	85.7	3	14.3	0	0	0	0	0	0	0	0	0	0	21	14.3	
18	85.7	3	14.3	0	0	0	0	0	0	0	0	0	0	21	14.3	
35	100.0	0	0	0	0	0	0	0	0	0	0	0	0	35	0	
32	91.4	2	5.7	1	2.9	0	0	0	0	0	0	0	0	35	8.6	
29	82.9	6	17.1	0	0	0	0	0	0	0	0	0	0	35	17.1	
18	94.7	0	0	1	5.3	0	0	0	0	0	0	0	0	19	5.3	(6)
18	94.7	0	0	1	5.3	0	0	0	0	0	0	0	0	19	5.3	
14	73.7	4	21.1	1	5.3	0	0	0	0	0	0	0	0	19	26.3	
18	85.7	1	4.8	2	9.5	0	0	0	0	0	0	0	0	21	14.3	
18	85.7	1	4.8	2	9.5	0	0	0	0	0	0	0	0	21	14.3	
16	76.2	5	23.8	0	0	0	0	0	0	0	0	0	0	21	23.8	
33	94.3	0	0	1	2.9	0	0	0	0	0	0	1	2.9	35	5.7	(7)
31	91.2	2	5.9	1	2.9	0	0	0	0	0	0	0	0	34	8.8	(4)
30	88.3	0	0	2	5.9	2	5.9	0	0	0	0	0	0	34	11.8	
21	100.0	0	0	0	0	0	0	0	0	0	0	0	0	21	0	
20	100.0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	(4)
18	90.0	2	10.0	0	0	0	0	0	0	0	0	0	0	20	10.0	
21	100.0	0	0	0	0	0	0	0	0	0	0	0	0	21	0	
21	100.0	0	0	0	0	0	0	0	0	0	0	0	0	21	0	
16	84.2	3	15.8	0	0	0	0	0	0	0	0	0	0	19	15.8	(6)

[4] One egg broken.
[5] Five-day experiment.
[6] Two eggs broken.
[7] Rot due to carelessness of farmers.

Detailed record of the cyclone-

Experiment No.	Kind of eggs.	Number used per day.	Total eggs.	Length of experiment.	Weather and temperature.	When candled.
112	Fertile.................	5	35	June 3-10...	Tables 3, 11; record 19.	On arrival in town........ Before leaving town....... Arrival at packing house..
113	Dirty, fertile...........	3	21	.....do......	.....do..........	On arrival in town........ Before leaving town....... Arrival at packing house..
114	Washed, fertile........	3	21	.....do......	.....do..........	On arrival in town........ Before leaving town....... Arrival at packing house..
131	Fertile.................	5	35	June 10-17...	Tables 3, 12; record 22.	On arrival in town........ Before leaving town....... Arrival at packing house..
132	Washed, fertile........	3	21	.....do......	.....do..........	On arrival in town........ Before leaving town....... Arrival at packing house..
142	Infertile...............	5	35	.....do......	.....do..........	On arrival in town........ Before leaving town....... Arrival at packing house..
143	Washed, infertile......	3	21	.....do......	.....do..........	On arrival in town........ Before leaving town....... Arrival at packing house..
157	Fertile.................	5	35	June 17-24...	Tables 3, 13; record 25.	On arrival in town........ Before leaving town....... Arrival at packing house..
158	Washed, fertile........	3	21	.....do......	.....do..........	On arrival in town........ Before leaving town....... Arrival at packing house..
159	Infertile...............	5	35	.....do......	.....do..........	On arrival in town........ Before leaving town....... Arrival at packing house..
160	Washed, infertile......	3	21	.....do......	.....do..........	On arrival in town........ Before leaving town....... Arrival at packing house..
180	Fertile.................	5	35	June 24-July 1.	Tables 3, 4, 14; record 28.	On arrival in town........ Before leaving town....... Arrival at packing house
181	Washed, fertile........	3	21	.....do......	.....do..........	On arrival in town........ Before leaving town....... Arrival at packing house..
182	Infertile...............	5	35	.....do......	.....do..........	On arrival in town........ Before leaving town....... Arrival at packing house..
183	Washed, infertile......	3	21	.....do......	.....do..........	On arrival in town........ Before leaving town....... Arrival at packing house..
203	Fertile.................	5	35	July 1-8.....	Tables 4, 15; record 31.	On arrival in town........ Before leaving town....... Arrival at packing house..
204	Washed, fertile........	3	21	.....do......	.....do..........	On arrival in town........ Before leaving town....... Arrival at packing house..
205	Infertile...............	5	35	.....do......	.....do..........	On arrival in town........ Before leaving town....... Arrival at packing house..
206	Washed, infertile......	3	21	.....do......	.....do..........	On arrival in town........ Before leaving town....... Arrival at packing house..
223	Fertile.................	5	35	July 8-15....	Tables 4, 16; record 34.	On arrival in town........ Before leaving town....... Arrival at packing house..
224	Washed, fertile........	3	21	.....do......	.....do..........	On arrival in town........ Before leaving town....... Arrival at packing house..
225	Infertile...............	5	35	.....do......	.....do..........	On arrival in town........ Before leaving town....... Arrival at packing house..
226	Washed, infertile......	3	21	.....do......	.....do..........	On arrival in town........ Before leaving town....... Arrival at packing house..
243	Fertile.................	5	35	July 15-22...	Tables 4, 17; record 37.	On arrival in town........ Before leaving town....... Arrival at packing house..

[1] One egg broken.

cave experiment—Continued.

Results of candling.														Total eggs candled.	Total deterioration (per cent).	Remarks.
Firsts.		Seconds.		Cracked.		Leakers.		Spots.		Blood rings.		Rots.				
Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.			
33	94.3	1	2.9	1	2.9	0	0	0	0	0	0	0	0	35	5.7	
29	82.9	4	11.4	2	5.7	0	0	0	0	0	0	0	0	35	17.1	
28	82.4	4	11.8	2	5.9	0	0	0	0	0	0	0	0	34	17.6	(1)
21	100.0	0	0	0	0	0	0	0	0	0	0	0	0	21	0	
21	100.0	0	0	0	0	0	0	0	0	0	0	0	0	21	0	
19	90.5	2	9.5	0	0	0	0	0	0	0	0	0	0	21	9.5	
21	100.0	0	0	0	0	0	0	0	0	0	0	0	0	21	0	
19	90.5	0	0	2	9.5	0	0	0	0	0	0	0	0	21	9.5	
18	85.7	2	9.5	1	4.8	0	0	0	0	0	0	0	0	21	14.3	
34	97.1	0	0	1	2.9	0	0	0	0	0	0	0	0	35	2.9	
34	97.1	0	0	1	2.9	0	0	0	0	0	0	0	0	35	2.9	
27	77.1	7	20.0	1	2.9	0	0	0	0	0	0	0	0	35	22.9	
20	100.0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	(1)
20	100.0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	
19	95.0	1	5.0	0	0	0	0	0	0	0	0	0	0	20	5.0	
34	97.1	0	0	1	2.9	0	0	0	0	0	0	0	0	35	2.9	
33	94.3	1	2.9	1	2.9	0	0	0	0	0	0	0	0	35	5.7	
32	91.4	2	5.7	1	2.9	0	0	0	0	0	0	0	0	35	8.6	
19	90.5	0	0	2	9.5	0	0	0	0	0	0	0	0	21	9.5	
19	90.5	0	0	2	9.5	0	0	0	0	0	0	0	0	21	9.5	
19	90.5	1	4.8	1	4.8	0	0	0	0	0	0	0	0	21	9.5	
33	94.3	1	2.9	1	2.9	0	0	0	0	0	0	0	0	35	5.7	
23	65.7	11	31.4	1	2.9	0	0	0	0	0	0	0	0	35	34.3	
3	8.6	32	91.4	0	0	0	0	0	0	0	0	0	0	35	91.4	
20	95.2	0	0	1	4.8	0	0	0	0	0	0	0	0	21	4.8	
10	47.6	10	47.6	1	4.8	0	0	0	0	0	0	0	0	21	52.4	
2	9.5	19	90.5	0	0	0	0	0	0	0	0	0	0	21	90.5	
32	91.4	2	5.7	1	2.9	0	0	0	0	0	0	0	0	35	8.6	
31	88.6	3	8.6	1	2.9	0	0	0	0	0	0	0	0	35	11.4	
4	11.4	31	88.6	0	0	0	0	0	0	0	0	0	0	35	88.6	
20	100.0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	(1)
20	100.0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	
1	5.0	19	95.0	0	0	0	0	0	0	0	0	0	0	20	95.0	
34	97.1	1	2.9	0	0	0	0	0	0	0	0	0	0	35	2.9	
22	62.9	13	37.1	0	0	0	0	0	0	0	0	0	0	35	37.1	
0	0	31	88.6	0	0	0	0	2	5.7	2	5.7	0	0	35	100.0	
20	95.2	0	0	0	0	0	0	0	0	1	4.8	0	0	21	4.8	
14	66.7	6	28.6	0	0	0	0	0	0	1	4.8	0	0	21	33.3	
1	4.8	19	90.5	1	4.8	0	0	0	0	0	0	0	0	21	95.2	
35	100.0	0	0	0	0	0	0	0	0	0	0	0	0	35	0	
35	100.0	0	0	0	0	0	0	0	0	0	0	0	0	35	0	
9	25.7	26	74.3	0	0	0	0	0	0	0	0	0	0	35	74.3	
21	100.0	0	0	0	0	0	0	0	0	0	0	0	0	21	0	
19	90.5	2	9.5	0	0	0	0	0	0	0	0	0	0	21	9.5	
4	19.0	17	81.0	0	0	0	0	0	0	0	0	0	0	21	81.0	
32	91.4	1	2.9	2	5.7	0	0	0	0	0	0	0	0	35	8.6	
21	60.0	13	37.1	1	2.9	0	0	0	0	0	0	0	0	35	40.0	
1	2.9	28	80.0	4	11.4	0	0	0	0	1	2.9	1	2.9	35	97.1	
21	100.0	0	0	0	0	0	0	0	0	0	0	0	0	21	0	
14	66.7	6	28.6	1	4.8	0	0	0	0	0	0	0	0	21	33.3	
1	4.8	19	90.5	0	0	0	0	0	0	1	4.8	0	0	21	95.2	
32	91.4	1	2.9	2	5.7	0	0	0	0	0	0	0	0	35	8.6	
30	85.7	3	8.6	2	5.7	0	0	0	0	0	0	0	0	35	14.3	
13	37.1	20	57.1	2	5.7	0	0	0	0	0	0	0	0	35	62.9	
21	100.0	0	0	0	0	0	0	0	0	0	0	0	0	21	0	
20	95.2	0	0	1	4.8	0	0	0	0	0	0	0	0	21	4.8	
8	38.1	13	61.9	0	0	0	0	0	0	0	0	0	0	21	61.9	
29	82.9	4	11.4	2	5.7	0	0	0	0	0	0	0	0	35	17.1	
29	82.9	4	11.4	2	5.7	0	0	0	0	0	0	0	0	35	17.1	
20	58.8	10	29.4	4	11.8	0	0	0	0	0	0	0	0	34	41.2	(1)
19	90.5	2	9.5	0	0	0	0	0	0	0	0	0	0	21	9.5	
19	90.5	2	9.5	0	0	0	0	0	0	0	0	0	0	21	9.5	
12	57.1	8	38.1	1	4.8	0	0	0	0	0	0	0	0	21	42.9	
34	97.1	0	0	1	2.9	0	0	0	0	0	0	0	0	35	2.9	
34	97.1	0	0	1	2.9	0	0	0	0	0	0	0	0	35	2.9	
27	77.1	6	17.1	2	5.7	0	0	0	0	0	0	0	0	35	22.9	
21	100.0	0	0	0	0	0	0	0	0	0	0	0	0	21	0	
21	100.0	0	0	0	0	0	0	0	0	0	0	0	0	21	0	
19	90.5	2	9.5	0	0	0	0	0	0	0	0	0	0	21	9.5	
32	94.1	1	2.9	1	2.9	0	0	0	0	0	0	0	0	34	5.9	(1)
32	94.1	1	2.9	1	2.9	0	0	0	0	0	0	0	0	34	5.9	
27	79.4	6	17.6	1	2.9	0	0	0	0	0	0	0	0	34	20.6	

Detailed record of the cyclone-

Experiment No.	Kind of eggs.	Number used per day.	Total eggs.	Length of experiment.	Weather and temperature.	When candled.
244	Washed, fertile........	3	21	July 15-22..	Tables 4, 17; record 37.	On arrival in town........ Before leaving town....... Arrival at packing house..
245	Infertile..............	5	35	.....do......	.....do..........	On arrival in town........ Before leaving town....... Arrival at packing house..
246	Washed, infertile......	3	21	.....do......	.....do..........	On arrival in town........ Before leaving town....... Arrival at packing house..
263	Fertile................	5	35	.....do......	.....do..........	On arrival in town........ Before leaving town....... Arrival at packing house..
264	Washed, fertile........	3	21	.....do......	.....do..........	On arrival in town........ Before leaving town....... Arrival at packing house..
265	Infertile..............	5	35	.....do......	.....do..........	On arrival in town........ Before leaving town....... Arrival at packing house..
266	Washed, infertile......	3	21	.....do......	.....do..........	On arrival in town........ Before leaving town....... Arrival at packing house..
283	Fertile................	5	35	July 29-Aug. 5.	Tables 4, 5, 19; record 43.	On arrival in town........ Before leaving town....... Arrival at packing house..
284	Washed, fertile........	3	21	.....do......	.....do..........	On arrival in town........ Before leaving town....... Arrival at packing house..
285	Infertile..............	5	35	.....do......	.....do..........	On arrival in town........ Before leaving town....... Arrival at packing house..
286	Washed, infertile......	3	21	.....do......	.....do..........	On arrival in town........ Before leaving town....... Arrival at packing house..
303	Fertile................	5	35	Aug. 5-12...	Tables 5, 20; record 46.	On arrival in town........ Before leaving town....... Arrival at packing house..
304	Washed, fertile........	3	21	.....do......	.....do..........	On arrival in town........ Before leaving town....... Arrival at packing house..
305	Infertile..............	5	35	.....do......	.....do..........	On arrival in town........ Before leaving town....... Arrival at packing house..
306	Washed, infertile......	3	21	.....do......	.....do..........	On arrival in town........ Before leaving town....... Arrival at packing house..
323	Fertile................	5	35	Aug. 12-19..	Tables 5, 21; record 49.	On arrival in town........ Before leaving town....... Arrival at packing house..
324	Washed, fertile........	3	21	.....do......	.....do..........	On arrival in town........ Before leaving town....... Arrival at packing house..
325	Infertile..............	5	35	.....do......	.....do..........	On arrival in town........ Before leaving town....... Arrival at packing house..
326	Washed, infertile......	3	21	.....do......	.....do..........	On arrival in town........ Before leaving town....... Arrival at packing house..
343	Fertile................	5	35	Aug. 19-26..	Tables 5, 22; record 52.	On arrival in town........ Before leaving town....... Arrival at packing house..
344	Washed, fertile........	3	21	.....do......	.....do..........	On arrival in town........ Before leaving town....... Arrival at packing house..
345	Infertile..............	5	35	.....do......	.....do..........	On arrival in town........ Before leaving town....... Arrival at packing house..
346	Washed, infertile......	3	21	....	....	On arrival in town........ Before leaving town....... Arrival at packing house..

---

[1] One egg broken.

cave experiment—Continued.

Results of candling.														Total eggs candled.	Total deterioration (per cent).	Remarks.
Firsts.		Seconds.		Cracked.		Leakers.		Spots.		Blood rings.		Rots.				
Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.			
20	95.2	1	4.8	0	0	0	0	0	0	0	0	0	0	21	4.8	
20	95.2	1	4.8	0	0	0	0	0	0	0	0	0	0	21	4.8	
19	90.5	2	9.5	0	0	0	0	0	0	0	0	0	0	21	9.5	
35	100.0	0	0	0	0	0	0	0	0	0	0	0	0	35	0	
35	100.0	0	0	0	0	0	0	0	0	0	0	0	0	35	0	
34	97.1	0	0	1	2.9	0	0	0	0	0	0	0	0	35	2.9	
21	100.0	0	0	0	0	0	0	0	0	0	0	0	0	21	0	
21	100.0	0	0	0	0	0	0	0	0	0	0	0	0	21	0	
21	100.0	0	0	0	0	0	0	0	0	0	0	0	0	21	0	
33	94.3	1	2.9	1	2.9	0	0	0	0	0	0	0	0	35	5.7	
33	94.3	1	2.9	1	2.9	0	0	0	0	0	0	0	0	35	5.7	
29	82.9	3	8.6	3	8.6	0	0	0	0	0	0	0	0	35	17.1	
21	100.0	0	0	0	0	0	0	0	0	0	0	0	0	21	0	
21	100.0	0	0	0	0	0	0	0	0	0	0	0	0	21	0	
15	71.4	5	23.8	0	0	0	0	1	4.8	0	0	0	0	21	28.6	
35	100.0	0	0	0	0	0	0	0	0	0	0	0	0	35	0	
35	100.0	0	0	0	0	0	0	0	0	0	0	0	0	35	0	
31	88.6	4	11.4	0	0	0	0	0	0	0	0	0	0	35	11.4	
20	95.2	1	4.8	0	0	0	0	0	0	0	0	0	0	21	4.8	
20	95.2	1	4.8	0	0	0	0	0	0	0	0	0	0	21	4.8	
18	85.7	3	14.3	0	0	0	0	0	0	0	0	0	0	21	14.3	
25	73.5	7	20.6	2	5.9	0	0	0	0	0	0	0	0	34	26.5	(1)
25	73.5	7	20.6	2	5.9	0	0	0	0	0	0	0	0	34	26.5	
19	55.9	12	35.3	3	8.8	0	0	0	0	0	0	0	0	34	44.1	
18	90.0	2	10.0	0	0	0	0	0	0	0	0	0	0	20	10.0	(1)
18	90.0	2	10.0	0	0	0	0	0	0	0	0	0	0	20	10.0	
13	65.0	6	30.0	1	5.0	0	0	0	0	0	0	0	0	20	35.0	
34	97.1	1	2.9	0	0	0	0	0	0	0	0	0	0	35	2.9	
34	97.1	1	2.9	0	0	0	0	0	0	0	0	0	0	35	2.9	
20	57.1	15	42.9	0	0	0	0	0	0	0	0	0	0	35	42.9	
18	85.7	3	14.3	0	0	0	0	0	0	0	0	0	0	21	14.3	
18	85.7	3	14.3	0	0	0	0	0	0	0	0	0	0	21	14.3	
12	57.1	9	42.9	0	0	0	0	0	0	0	0	0	0	21	42.9	
31	88.6	2	5.7	2	5.7	0	0	0	0	0	0	0	0	35	11.4	
30	85.7	3	8.6	2	5.7	0	0	0	0	0	0	0	0	35	14.3	
25	71.4	7	20.0	3	8.6	0	0	0	0	0	0	0	0	35	28.6	
20	95.2	1	4.8	0	0	0	0	0	0	0	0	0	0	21	4.8	
20	95.2	1	4.8	0	0	0	0	0	0	0	0	0	0	21	4.8	
20	95.2	1	4.8	0	0	0	0	0	0	0	0	0	0	21	4.8	
35	100.0	0	0	0	0	0	0	0	0	0	0	0	0	35	0	
35	100.0	0	0	0	0	0	0	0	0	0	0	0	0	35	0	
33	94.3	1	2.9	1	2.9	0	0	0	0	0	0	0	0	35	5.7	
21	100.0	0	0	0	0	0	0	0	0	0	0	0	0	21	0	
21	100.0	0	0	0	0	0	0	0	0	0	0	0	0	21	0	
21	100.0	0	0	0	0	0	0	0	0	0	0	0	0	21	0	
26	74.3	9	25.7	0	0	0	0	0	0	0	0	0	0	35	25.7	
24	68.6	11	31.4	0	0	0	0	0	0	0	0	0	0	35	31.4	
18	51.4	17	48.6	0	0	0	0	0	0	0	0	0	0	35	48.6	
18	85.7	2	9.5	1	4.8	0	0	0	0	0	0	0	0	21	14.3	
17	81.0	3	14.3	1	4.8	0	0	0	0	0	0	0	0	21	19.0	
13	61.9	7	33.3	1	4.8	0	0	0	0	0	0	0	0	21	38.1	
34	97.1	0	0	1	2.9	0	0	0	0	0	0	0	0	35	2.9	
32	91.4	2	5.7	1	2.9	0	0	0	0	0	0	0	0	35	8.6	
26	74.3	6	17.1	3	8.6	0	0	0	0	0	0	0	0	35	25.7	
15	71.4	5	23.8	1	4.8	0	0	0	0	0	0	0	0	21	28.6	
14	66.7	6	28.6	1	4.8	0	0	0	0	0	0	0	0	21	33.3	
15	71.4	5	23.8	1	4.8	0	0	0	0	0	0	0	0	21	28.6	
33	94.3	2	5.7	0	0	0	0	0	0	0	0	0	0	35	5.7	
33	94.3	2	5.7	0	0	0	0	0	0	0	0	0	0	35	5.7	
29	85.3	4	11.8	1	2.9	0	0	0	0	0	0	0	0	34	14.3	(1)
17	85.0	3	15.0	0	0	0	0	0	0	0	0	0	0	20	15.0	(1)
17	85.0	3	15.0	0	0	0	0	0	0	0	0	0	0	20	15.0	
18	90.0	1	5.0	0	0	0	0	0	0	0	0	0	0	20	10.0	
35	100.0	0	0	0	0	0	0	0	0	0	0	0	0	35	0	
35	100.0	0	0	0	0	0	0	0	0	0	0	0	0	35	0	
35	100.0	0	0	0	0	0	0	0	0	0	0	0	0	35	0	
20	95.2	1	4.8	0	0	0	0	0	0	0	0	0	0	21	4.8	
20	95.2	1	4.8	0	0	0	0	0	0	0	0	0	0	21	4.8	
21	100.0	0	0	0	0	0	0	0	0	0	0	0	0	21	0	

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A. D. MELVIN, CHIEF OF BUREAU.

A STUDY OF THE BACTERIA WHICH SURVIVE PASTEURIZATION.

BY

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AND

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WASHINGTON:
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1913.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Animal Industry,
Washington, D. C., October 7, 1912.

Sir: I have the honor to transmit herewith for publication in the bulletin series of this bureau a manuscript entitled "A Study of the Bacteria Which Survive Pasteurization," by Messrs. S. Henry Ayers and William T. Johnson, jr., of the Dairy Division.

Respectfully,

A. D. Melvin,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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A STUDY OF BACTERIA WHICH SURVIVE PASTEURIZATION.

INTRODUCTION.

The bacteria which survive the process of pasteurization are of great importance, since they form the foundation for the subsequent bacterial development. It is well known that the most efficient pasteurization will not destroy all of the microorganisms in milk. The process must, then, leave a certain number of bacteria which it is impossible to destroy at the temperatures employed.

The prevailing view has been that the organisms left after heating were largely of the peptonizing spore-forming type, with some few inert forms. This idea was based on the belief that all vegetative cells were destroyed at temperatures below the minimum pasteurizing temperature of 60° C. (140° F.).

Theoretically, then, only spore-forming organisms should survive pasteurization. This view was strengthened by numerous investigations of the bacterial flora of boiled milk or milk pasteurized at extremely high temperatures. As lower temperatures came gradually into use investigations indicated that vegetative cells might have higher thermal death points than was generally believed. Russell and Hastings[1] found a micrococcus which was capable of standing a temperature of 76° C. (168.8° F.) for 10 minutes. Other investigators pointed out that lactic acid bacteria occasionally appeared in pasteurized milk and yet the thermal death point of the lactic acid bacteria was stated to be in the neighborhood of 57.2° to 60° C. (135°-140° F.). Rogers[2] found that in milk pasteurized at 85° C. (185° F.) by the "flash" process lactic acid bacteria occasionally survived. Marshall[3] states "It is largely supposed that in pasteurized milk the lactic acid bacteria are killed. This is largely true but not universally." Mazé[4] found that the ordinary lactic acid bacteria were destroyed by five minutes' heating at temperatures between 55° and 65° C. (131° and 149° F.), but that lactic acid bacteria existed which resist five minutes' heating at 75° C. (167° F.). When milk was pasteurized in bottles for 60 minutes at 65° C. (149° F.), Gerber[1] and Weiske found that the bacteria which resisted belonged for the most part to the inoffensive lactic bacilli. An investigation of commercially pasteurized milk in this country carried on by the authors[2] showed the presence of high-temperature resisting lactic-acid bacteria, the thermal death point of one of which was 77.8° C. (172° F.) with a 10 minutes' exposure and 75.6° C. (168° F.) with a 30 minutes' heating. It was further found that commercially pasteurized milk always soured. Kohler[3] and Tonney, after studying pasteurized milk in Chicago, concluded that reinfection was the cause of the souring of heated milk.

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[1] Russell, H. L., and Hastings, E. G. A micrococcus, the thermal death limit of which is 76° C. Centralblatt für Bakteriologie, Parasitenkunde und Infektionskrankheiten, Abteilung 2, vol. 8, No. 11, pp. 339-342. Jena, Mar. 13, 1902.

[2] Rogers, L. A. The bacteria of pasteurized and unpasteurized milk under laboratory conditions. United States Department of Agriculture, Bureau of Animal Industry, Bulletin 73. Washington, 1905.

[3] Marshall, C. E. Pasteurization of milk. Michigan Agricultural Experiment Station, Bulletin 147. Agricultural College, August, 1897.

[4] Mazé, P. Pasteurization du lait destiné à la consommation. L'Industrie Laitière, vol. 32, No. 8, pp. 121-127. Paris, Feb. 24, 1907.

It is evident that the knowledge of the bacteria which actually survive pasteurization is very limited.

OBJECTS OF THIS INVESTIGATION.

The general object of this investigation was to study quantitatively and qualitatively the bacteria which survive pasteurization under conditions which excluded any possibility of recontamination of the milk after pasteurization.

The special objects were as follows:

1. To ascertain the average temperature of pasteurization in both the "holder" and "flash" process used throughout the country.
2. To determine the effect of various pasteurizing temperatures for one-half hour's exposure upon the bacteria in different grades of milk.
3. To study the effect of holding periods longer than one-half hour during pasteurization.
4. To determine the effect of sudden cooling on bacteria after pasteurization.
5. To study quantitatively the bacterial groups which survive pasteurization at various temperatures.
6. To trace the development of the various bacterial groups in pasteurized milk held at different temperatures.
7. To study qualitatively the bacteria which survive pasteurization.

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[1] Gerber, N., and Weiske, P. Pasteurisation des flacons dans la grande industrie (pasteurisation avec agitation). Revue Générale du Lait, vol. 2, No. 8, pp. 169-177. Lierre, Jan. 30, 1903.

[2] Ayers, S. Henry, and Johnson, W. T., jr. The bacteriology of commercially pasteurized and raw market milk. United States Department of Agriculture, Bureau of Animal Industry, Bulletin 126. Washington, 1910.

[3] Kohler, Gottfried and Tonney, F. O. The control of pasteurization. Journal of the American Medical Association, vol. 56, No. 10, pp. 713-718. Chicago, Mar. 11, 1911.

METHODS.

In this investigation the technique of plating and the preparation of beef infusion agar with a reaction of 1.5 (Fuller's scale) was carried out according to the recommendations of the committee of standard methods for the bacteriological analyses of milk.[1] In the preparation of fermentation bouillons and litmus lactose gelatin, Liebig's beef extract was used as a basis.

Fermentation bouillons were prepared by dissolving 4 grams of Liebig's beef extract and 10 grams of Witte's peptone in a liter of water and correcting reaction to 0.0 (Fuller's scale). The broth was then brought up to the sterilizing temperature for five minutes and filtered. When a clear filtrate was obtained, 0.5 per cent potassium dibasic phosphate and 1 per cent of the substance to be fermented was dissolved in it. The following substances were used to test the fermenting ability of the bacteria:

Sugars: Dextrose, galactose, lactose, saccharose, raffinose. Alcohols: Mannite, glycerin. Starches: Inulin, wheat starch. Glucoside: Salicin.

The ability of the bacteria to reduce nitrates to nitrites was shown by growing the organisms in a bouillon composed of 0.1 per cent Witte's peptone and 0.02 per cent potassium nitrate (nitrite-free) for 14 days at 30° C. (86° F.) and then testing for the presence of nitrites. The liquefaction of gelatin by an organism was determined by inoculating with a drop of milk culture on the surface of the tube of medium and incubating for 30 days at 18° C. (64.4° F.) and then measuring the depth of liquefaction.

Special media.—For ordinary routine plating of a milk sample, and especially for the determination of the peptonizing bacteria, a casein agar was devised,[2] consisting of dissolved chemically pure casein and agar, with a final reaction slightly acid. In isolating gas formers, Smith tubes containing lactose peptone bile [3] and dextrose liver broth [4] were used.

All samples of milk were pasteurized in sterile flasks in the laboratory. At all the temperatures except 60° C. (140° F.) and 65.6° C. (150° F.), 800 cubic centimeters of milk were heated. During the few experiments at those temperatures only 100 cubic centimeters of milk were used. In all the experiments the period of heating was 30 minutes from the time the pasteurizing temperature was reached. The methods employed throughout this investigation make the results comparable with those obtained by pasteurization in sealed bottles.

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[1] Report of the Committee on Standard Methods of Bacterial Milk Analysis. American Journal of Public Hygiene, new series, vol. 6, No. 2, pp. 315–345. Columbus, Ohio, May, 1910.

[2] Ayers, S. Henry. Casein media adapted to determining bacteria in milk. United States Department of Agriculture, Bureau of Animal Industry, Twenty-eighth Annual Report, 1911 (in press).

[3] Jackson, Daniel D. A new solution for the presumptive test for *Bacillus coli*. Biological Studies of Pupils of W. T. Sedgwick, pp. 292–299. Boston, 1906.

[4] Jackson, D. D., and Muer, T. C. Liver broth. A medium for the determination of gas-forming bacteria in water and sewage. Journal of the American Public Health Association, vol. 1, No. 12, pp. 927–929. Urbana, Ill., December, 1911.

TEMPERATURES USED THROUGHOUT THE COUNTRY.

It was necessary to ascertain the temperatures most universally used at milk plants in this country in order that an average temperature might be employed in these experiments. Circular letters were therefore sent to pasteurizing plants in nearly all cities with a population of over 25,000. Replies showed that the average temperature with the "holder" process was 62.8° C. (145° F.). With the "flash" process 71.1° C. (160° F.) was about the average. The reports from 219 milk plants which pasteurized showed that 75 used the "holder" process and 144 the "flash" process.

Assuming that the correct temperatures for pasteurization are from 60° to 65.6° C. (140° to 150° F.) with the "holder" process, then 62 of the 75 pasteurized at the proper temperature, one used a temperature too low, 54.4° to 57.2° C. (130° to 135° F.), and 12 too high, ranging from 66.7° to 76.7° C. (152° to 170° F.). With the "flash" process the correct temperature was assumed to be 71.1° C. (160° F.). As there is usually a variation in the range of temperature during pasteurization, the maximum and the minimum given by each plant have been averaged. When the average was 71.1° C. (160° F.) it was assumed that the proper temperature was used. It was found that of 144 plants using the "flash" process only 61 used the correct temperature, 61 pasteurized too low and 22 too high. The low temperatures ran down to 60° C. (140° F.), the high temperatures up to 82.2° C. (180° F.). These figures show a decided lack of uniformity of temperatures used in pasteurization. The temperatures below 60° C. (140° F.) with the "holder" process render no protection as far as the destruction of pathogenic organisms is concerned, while those above 65.6° C. (150° F.) only increase the cost of pasteurization and tend to reduce the cream line. The same is true when using the "flash" process below or above temperatures ranging from 71.1° to 73.9° C. (160° to 165° F.).

As pasteurization is practiced, the milk might have been heated from 1 minute at 60° C. (140° F.) to 30 minutes at 76.7° C. (170° F.) and it would all be known as pasteurized milk. This lack of uniformity is undoubtedly due to a misunderstanding of the effects of heat on the bacterial flora of milk.

BACTERIAL REDUCTIONS BY LABORATORY PASTEURIZATION, USING THE "HOLDER" PROCESS.

Since regulations often require a definite percentage bacterial reduction and as the efficiency of pasteurizers is based on the same figures, it seemed advisable to study the quantitative bacterial reductions under exact laboratory conditions.

BACTERIAL REDUCTIONS AT 60° C. (140° F.) AND 65.6° C. (150° F.).

In these experiments the milk was heated in sterile flasks in a water bath at a temperature of 60° C. (140° F.) and 65.6° C. (150° F.) for a period of 30 minutes. The temperature recorded by a thermometer in the milk was maintained for the full 30 minutes. Twelve samples of milk from dairy X were used. Each was divided and a portion pasteurized at both temperatures. The counts were made on litmus lactose gelatin incubated at 18° C. (64.4° F.) for six days. Table 1 shows the total counts and efficiency of the process as determined by the percentage bacterial reduction. An examination of the table shows that the raw milk was of poor quality, having a high bacterial count. The samples pasteurized at 60° C. (140° F.) showed a high count, while the same samples at 65.6° C. (150° F.) showed a low count, as a rule. The effect of the few degrees of heat may be plainly seen. At the lower temperature 9 out of the 12 samples showed a reduction of less than 99 per cent, while at the higher temperature only 4 showed less than a 99 per cent reduction.

TABLE 1.—*Percentage reduction of bacteria by laboratory pasteurization, using the "holder" process—Raw milk obtained from dairy X.*

Sample No.	Raw milk.	Pasteurized at 60° C. (140° F.) for 30 minutes.		Pasteurized at 65.6° C. (150° F.) for 30 minutes.	
	Total count.	Total count.	Percentage reduction.	Total count.	Percentage reduction.
1	33,900,000	200,000	99.41	9,800	99.97
2	4,900,000	118,000	97.59	12,300	99.74
3	5,060,000	130,000	97.45	25,100	99.50
4	850,000	32,000	96.23	25,500	97.00
5	6,100,000	20,200	99.66	12,100	99.80
6	8,400,000	23,000	99.72	12,600	99.85
7	1,670,000	284,000	82.99	72,000	95.68
8	4,100,000	74,000	98.19	28,500	99.30
9	1,120,000	56,000	95.00	19,900	98.22
10	4,800,000	153,000	96.81	19,800	99.58
11	4,400,000	206,000	95.31	69,000	98.43
12	12,300,000	196,000	98.41	40,000	99.67

The effect of pasteurization on the bacterial content of another series of 12 samples from dairy Y was studied in the same way. The results are shown in Table 2. It may be seen that the milk was of far better quality than that from dairy X. The counts of milk pasteurized at 60° C. (140° F.) were low and still lower at the higher temperature. In spite of the low counts the percentage bacterial reductions were not so great as when a poor grade of milk was pasteurized as shown in Table 1. Eleven out of twelve samples showed a reduction of less than 99 per cent at 60° C. (140° F.). At 65.6° C. (150° F.) 7 out of 12 showed a bacterial reduction of less than 99 per cent. A comparison of Tables 1 and 2 show that the bacterial content after pasteurization of the better grade of milk was far lower than that of milk from dairy X, which contained a large number of bacteria before heating. If, however, the efficiency of the process is studied, the higher percentage bacterial reductions will be found in Table 1, where the milk was of poor quality. It is very evident that the percentage bacterial reduction is of no value in determining the quality of pasteurized milk. Compare, for example, sample No. 1 in Table 1 with sample No. 3 in Table 2. In the first case, the raw milk contained 33,900,000 bacteria per cubic centimeter and after pasteurization 200,000 per cubic centimeter, which is a percentage reduction of 99.41 per cent. In the second case, raw milk, 128,000 bacteria per cubic centimeter and after pasteurization 13,900 per cubic centimeter, which is a reduction of only 89.14 per cent. A 99.41 per cent reduction against 89.14 per cent, and yet the pasteurized milk in which only 89.14 per cent of the bacteria were destroyed was far superior in its bacterial content.

TABLE 2.—*Percentage reduction of bacteria by laboratory pasteurization, using the "holder" process—Raw milk obtained from dairy Y.*

Sample No.	Raw milk.	Pasteurized at 60° C. (140° F.) for 30 minutes.		Pasteurized at 65.6° C. (150° F.) for 30 minutes.	
	Total count.	Total count.	Percentage reduction.	Total count.	Percentage reduction.
1	2,500,000	27,600	98.89	4,210	99.83
2	1,090,000	13,100	98.79	2,320	99.78
3	128,000	13,900	89.14	5,670	95.57
4	149,000	7,500	94.96	3,100	97.91
5	600,000	16,400	97.26	11,100	98.15
6	119,000	2,530	97.87	1,020	99.14
7	168,000	1,890	98.87	3,230	98.07
8	84,000	2,600	96.90	2,720	96.76
9	160,000	5,110	96.80	2,010	98.74
10	590,000	13,200	97.76	7,100	98.79
11	2,900,000	28,700	99.01	20,400	99.29
12	1,170,000	34,100	97.08	3,560	99.69

The uselessness of figures in expressing percentage reductions is further shown in Table 3. The bacterial content of 12 samples of milk before and after pasteurization has been averaged, two grades of milk having been used. While the percentage reduction is approximately the same at 60° C. (140° F.) the average bacterial counts vary widely, one being 124,000 per cubic centimeter, the other only 13,900 per cubic centimeter. At 65.6° C. (150° F.) while the percentage reduction is increased to 98 per cent, the bacterial content holds the same relation as at the lower temperature.

TABLE 3.—*Comparison of the average bacterial content of two grades of milk and percentage reduction in bacteria by pasteurization at 60° C. (140° F.) and 65.6° C. (150° F.).*

AVERAGE OF 12 SAMPLES IN EACH GRADE.

Grade.	Raw milk.	Pasteurized at 60° C. (140° F.) 30 minutes.		Pasteurized at 65.6° C. (150° F.) 30 minutes.	
	Bacteria per cubic centimeter.	Bacteria per cubic centimeter.	Percentage reduction.	Bacteria per cubic centimeter.	Percentage reduction.
Grade 1....	7,300,000	124,000	96.39	28,900	98.72
Grade 2....	804,000	13,900	96.95	5,500	98.40

BACTERIAL REDUCTION AT 62.8° C. (145° F.).

Another series of 28 samples of milk was studied in a similar manner. The results are shown in Table 4. In this series a temperature of 62.8° C. (145° F.) was used for a period of 30 minutes. All of the samples of raw milk contained over 1,000,000 bacteria per cubic centimeter. The bacterial counts were made on infusion agar, incubated at 30° C. (86° F.) for six days. It may be seen from the table that the percentage reductions were high, only 3 out of 28 being less than 99 per cent; however, 13 of the pasteurized samples contained over 20,000 bacteria per cubic centimeter.

TABLE 4.—*Efficiency of the "holder" process of pasteurization under laboratory conditions, using raw milk with a bacterial content over 1,000,000 per cubic centimeter.*

Sample No.	Raw milk.	Pasteurized at 62.8° C. (145° F.) for 30 minutes.		Sample No.	Raw milk.	Pasteurized at 62.8° C. (145° F.) for 30 minutes.	
	Bacteria per cubic centimeter.	Bacteria per cubic centimeter.	Percentage reduction.		Bacteria per cubic centimeter.	Bacteria per cubic centimeter.	Percentage reduction.
1	16,800,000	85,000	99.49	15	12,200,000	33,300	99.72
2	91,000,000	14,400	99.98	16	28,200,000	127,000	99.54
3	15,900,000	18,200	99.88	17	6,480,000	2,400	99.96
4	90,000,000	5,800	99.99	18	4,540,000	9,500	99.97
5	19,800,000	41,000	99.79	19	2,460,000	13,600	99.44
6	105,000,000	17,500	99.98	20	4,900,000	9,900	99.79
7	47,300,000	8,900	99.98	21	1,060,000	1,010	99.90
8	12,400,000	9,700	99.92	22	2,790,000	8,800	99.68
9	8,600,000	15,000	99.82	23	5,400,000	36,600	99.32
10	17,800,000	8,900	99.95	24	6,060,000	30,100	99.50
11	18,900,000	41,800	99.97	25	1,140,000	1,560	99.86
12	15,100,000	39,700	99.74	26	14,600,000	468,000	96.79
13	22,000,000	20,400	99.90	27	1,440,000	22,900	98.41
14	98,000,000	28,200	99.97	28	1,780,000	26,500	98.51

The results of similar experiments using a series of 24 samples of clean milk are shown in Table 5. The bacterial counts of the pasteurized milk were very low as a rule and yet 14 of the 24 samples showed a percentage bacterial reduction of less than 99 per cent. Sample 17 contained, before heating, only 119,000 bacteria per cubic centimeter; after the process the bacterial content was 20,800, a reduction of only 82.52 per cent. This sample evidently contained a high percentage of resistant bacteria which were able to withstand the process of pasteurization. From these results it is apparent that regulations of boards of health calling for a 99 per cent reduction of bacteria in commercial pasteurization are of no value. As a general rule, it may be said that the higher the bacteria in raw milk the greater the percentage reduction through pasteurization. When the bacterial content of milk is low it is almost always impossible to obtain a 99 per cent reduction of the bacteria. It is also evident that bacterial standards for pasteurized milk must not be set below the limit which it is theoretically possible to obtain. When pasteurizing in the laboratory for a period of 30 minutes at 62.8° C. (145° F.) under conditions which permitted no reinfection of the milk, the bacterial content of pasteurized milk was by no means uniform. Sometimes the counts were high and sometimes low and yet the maintenance of the proper temperature of pasteurization would have assured in all cases the same degree of protection from pathogenic organisms.

TABLE 5.—*Efficiency of the "holder" process of pasteurization under laboratory conditions, using raw milk with a bacterial content less than 1,000,000 per cubic centimeter.*

Sample No.	Raw milk.	Pasteurized at 62.8° C (145° F.) for 30 minutes.		Sample No.	Raw milk.	Pasteurized at 62.8° C. (145° F.) for 30 minutes.	
	Bacteria per cubic centimeter.	Bacteria per cubic centimeter.	Percentage reduction.		Bacteria per cubic centimeter.	Bacteria per cubic centimeter.	Percentage reduction.
1	372,000	910	99.75	13	540,000	11,800	97.81
2	434,000	2,330	99.46	14	970,000	46,000	95.25
3	540,000	4,890	99.09	15	162,000	8,400	94.81
4	410,000	1,170	99.71	16	118,000	9,000	92.37
5	127,000	80	99.93	17	119,000	20,800	82.52
6	143,000	765	99.46	18	137,000	3,100	97.73
7	9,300	90	99.03	19	15,600	300	98.07
8	18,100	180	99.00	20	9,800	100	98.97
9	19,900	62	99.68	21	18,700	1,340	92.83
10	5,300	34	99.35	22	25,900	830	96.79
11	134,000	7,500	94.40	23	15,300	334	97.81
12	300,000	7,600	97.47	24	9,900	320	96.76

THE CONTROL OF PASTEURIZATION.

The control of the process of pasteurization should be by bacterial limits for the milk which is to be used, together with supervision for the maintenance of the proper pasteurizing temperature and protection against reinfection. The bacterial content of the milk will then consist only of those organisms which are able to withstand the temperature in use.

EFFECT OF LONG HEATING ON THE BACTERIA IN MILK.

In some milk plants a holding period longer than half an hour is employed. It seems to be believed that an increased holding period produces a greater bacterial reduction. Several experiments were made at different temperatures and for different periods in order to gain more information on this point.

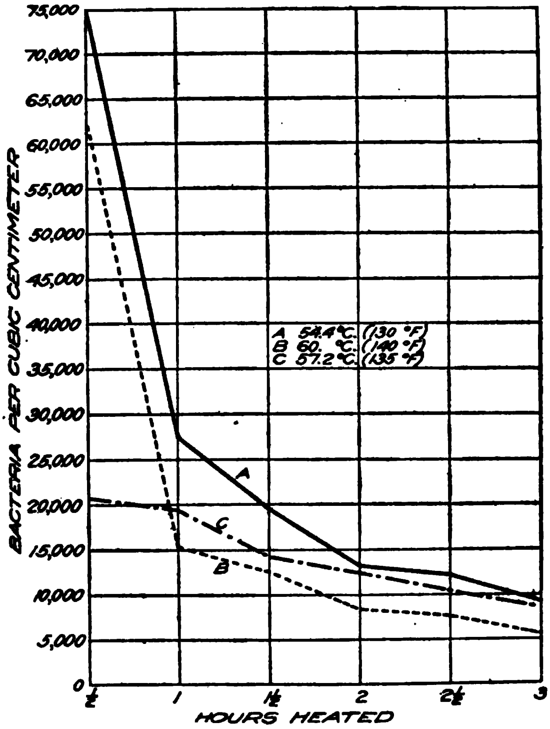

FIG. 1.—Bacterial reduction during pasteurization for three hours at 54.4° C. (130° F.), 57.2° C. (135° F.), and 60° C. (140° F.).

THREE HOURS' PASTEURIZATION.

In order to determine the effect of a long period of pasteurization, milk was heated in sterile flasks at 54.4° C. (130° F.), 57.2° C. (135° F.), and 60° C. (140° F.), and plated every half hour for three hours. The bacterial counts are shown in Table 6. One sample of milk was divided and a portion heated at the two lower temperatures, so the bacterial content of the raw milk was the same. The sample of milk heated at 60° C. (140° F.) contained approximately the same number of bacteria per cubic centimeter and was from the same dairy, so it is probably fair to compare the results. After one-half hour's heating a much greater reduction was observed where the milk was heated at 60° C. (140° F.). At the end of one hour's heating the bacterial content of the milk were more nearly alike and continued to show a gradual reduction throughout the three hours of heating. The final examination showed that the bacterial content was approximately the same in all the samples of milk. The bacterial reductions are shown better by the curves in figure 1. It is evident that long heating at 54.4° C (130° F.) and 57.2° C. (135° F.) is of more value than at 60° C. (140° F.), as shown by curves A, B, and C, respectively. From a comparison of curves A and C it seems that one and a half hours' heating at 54.4° C. (130° F.) will produce as great a bacterial reduction as one-half hour's heating at 60° C. (140° F.). It must not be assumed, however, that one and one-half hours' heating at 54.4° C. (130° F.) will destroy pathogenic organisms as surely as will one-half hour's heating at 60° C. (140° F.). That point can only be determined by experiment.

TABLE 6.—*Bacterial reduction during pasteurization for 3 hours at 54.4° C. (130° F.), 57.2° C. (135° F.), and 60° C. (140° F.).*

Temperature of pasteurization.		Bacteria per cubic centimeter in raw milk.	Bacteria per cubic centimeter in milk pasteurized for—					
			½ hour.	1 hour.	1½ hours.	2 hours.	2½ hours.	3 hours.
°C.	*°F.*							
54.4	130	2,530,000	75,000	27,600	19,400	13,200	12,300	9,200
57.2	135	2,530,000	63,000	15,400	12,600	8,400	7,900	5,600
60.0	140	2,330,000	20,800	19,400	14,100	12,400	10,300	8,700

SIX HOURS' PASTEURIZATION.

A similar experiment was made, using a six hours' period of heating at 62.8° C. (145° F.). In order to meet extreme conditions where the effect of long heating might show, a milk containing 27,000,000 bacteria per cubic centimeter was selected. Plates were made every half hour during the period of heating. Table 7 shows the results.

TABLE 7.—*Bacterial reductions during pasteurization for 6 hours at 62.8° C. (145° F.)*

Length of pasteurization (hours).	Bacteria per cubic centimeter.	Length of pasteurization (hours).	Bacteria per cubic centimeter.
Raw	27,000,000	3½	32,900
½	46,000	4	31,200
1	46,000	4½	44,000
1½	45,000	5	35,700
2	65,000	5½	39,000
2½	62,000	6	34,500
3	54,000		

It may be seen that there was little difference in the bacterial reduction produced by a half hour's heating and by six hours' heating. There were numerous variations in the numbers of bacteria as determined, but they were within the experimental error, as the flask of heated milk could not be thoroughly shaken. In this experiment the groups of bacteria which withstood the heating were determined. The plating was done on infusion agar plates, which were incubated at

30° C. (86° F.) for six days. The plates were counted and then each colony picked from a plate and inoculated into litmus milk tubes. After 14 days' incubation the milk cultures were examined and as a result of the reactions shown the bacteria picked from the plates were divided into five groups, the acid forming and coagulating, acid-forming, inert, alkali-forming, and peptonizing groups. The value of this method of determining bacterial groups will be discussed later in this paper. Figure 2 shows the relations of the groups after heating one-half hour, three hours, and six hours. The acid-coagulating and simple acid-forming groups composed the largest portion of the bacteria after a half hour's heating and the same after six hours' pasteurization. It may be seen, however, that the percentage of the acid-coagulating group was reduced by the heating for six hours. It seems probable that the heating weakened the activity of the acid-forming bacteria so that in the litmus milk tubes not enough acid was produced to coagulate the milk in the 14 days' incubation period. That would result in a lowering of the percentage of the acid-coagulating group, while increasing at the same time the simple acid-forming group. The percentage of the alkali and peptonizing groups was extremely low throughout the experiment. In figure 3 the group percentages have been plotted at every half hour's sampling and gives a more complete picture of the changes in the bacterial groups. The changes in the group percentages between three and one-half and four hours is undoubtedly due to the errors in sampling and inaccuracy of the method of the bacterial group differentiation.

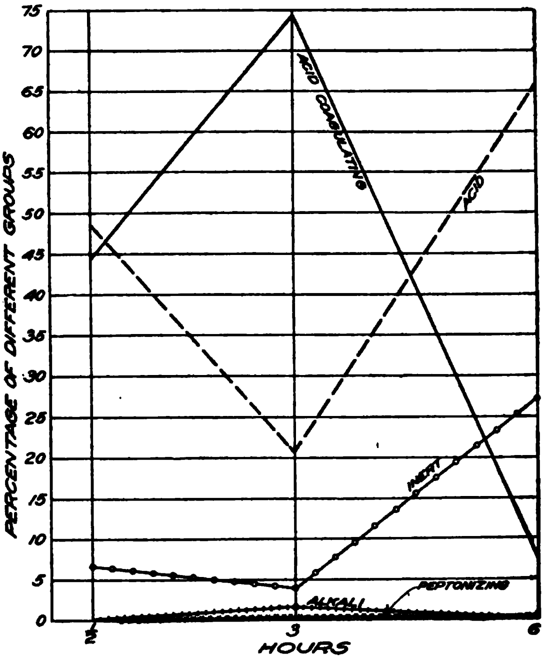

FIG. 2.—Bacterial reduction during pasteurization for six hours at 62.8° C. (145° F.). Plotted after one-half, three, and six hours.

EFFECT OF SUDDEN COOLING ON THE BACTERIA IN PASTEURIZED MILK.

The sudden cooling of the hot milk after pasteurization has been considered by many to be an essential part of the process. It was believed that the sudden change from hot to cold aided in the destruction of the bacteria. In the recent developments of the process of pasteurization, however, this opinion lost ground, although at the present time there are those who still believe in its value. In order to throw light on this point a few experiments were made under laboratory conditions. Samples of milk were pasteurized in sterile flasks, then cooled by running through a sterile copper coil surrounded by brine into another sterile flask. Table 8 shows the results of the experiments. Two samples of milk were pasteurized at 62.8° C. (145° F.) for 30 minutes, then cooled in 15 seconds to from 1.7°–3.9° C. (35°–39° F.). The experiment was repeated, using a period of 30 minutes' heating at 71.1° C. (160° F.). The bacterial content of the milk before and after cooling was approximately the same, the differences always being within the limits of experimental error. It is evident from the results shown in the table that sudden cooling is of no value in causing a destruction of bacteria, at least not at the temperatures used in the experiments.

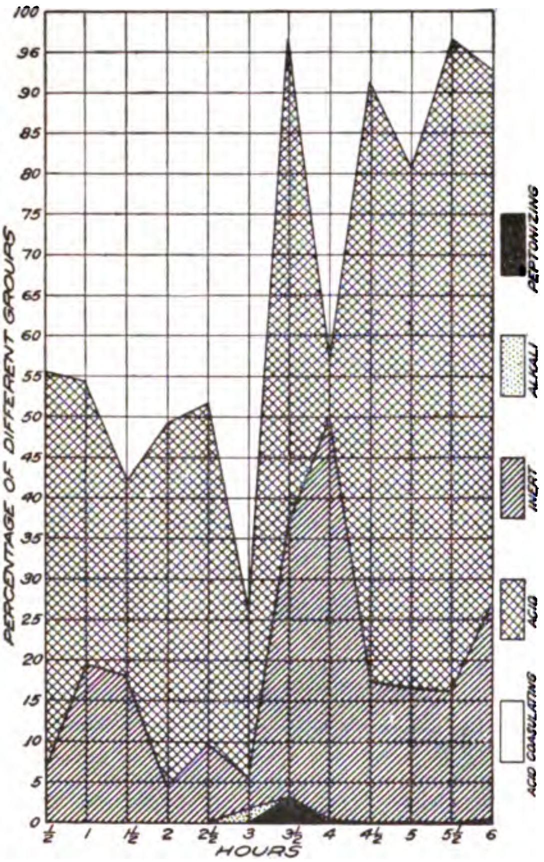

FIG. 3.—Bacterial reduction during pasteurization for six hours at 62.8° C. (145° F.). Plotted every half hour.

TABLE 8.—*Effect of sudden cooling on the bacterial content of pasteurized milk.*

Sample No.	Bacteria per cubic centimeter in raw milk.	Pasteurized at 62.8° C. (145° F.) 30 minutes.		Sample No.	Bacteria per cubic centimeter in raw milk.	Pasteurized at 71.1° C. (160° F.) 30 minutes.	
		Bacteria per cubic centimeter in milk not cooled.	Bacteria per cubic centimeter in cooled milk.			Bacteria per cubic centimeter in milk not cooled.	Bacteria per cubic centimeter in cooled milk.
1	186,000	8,600	8,500	3	400,000	1,880	1,950
2	233,000	1,470	2,160	4	1,350,000	1,750	1,700

The value of sudden cooling then, lies in the fact that milk after pasteurization is not allowed to cool slowly through temperatures below 37.8° C. (100° F.) where a rapid development of bacteria might occur.

GROUPS OF BACTERIA WHICH SURVIVE PASTEURIZATION.

The most important feature of this investigation has been the determination of the various groups of bacteria which survive the process of pasteurization. These bacteria form the basis of the bacterial growth in pasteurized milk.

GRADES OF MILK STUDIED.

Since the bacterial groups in various grades of milk vary with the quality of the milk, it was decided to examine three grades—one of poor quality, one of fair quality, and one of good quality. The bacterial content of each of the samples of the three grades has been averaged as shown in Table 9. With poor milk designated grade A, the average of 20 samples showed a bacterial content of 32,950,000 per cubic centimeter. An average of 24 samples of grade B showed 3,451,000 per cubic centimeter, while the average bacterial count of 12 samples of grade C milk showed 24,700 per cubic centimeter.

TABLE 9.—*Grades of milk studied.*

Grade.	Average number of bacteria per cubic centimeter.	Number of samples averaged.
A	32,950,000	20
B	3,451,000	24
C	24,700	12

METHODS.

In the determination of the bacterial groups a method was employed which may be designated as the milk-tube method. This method, as described earlier in this paper, consists in picking off each colony on the plate and inoculating it into litmus milk tubes. The milk tubes were incubated for 14 days at 30° C. (86° F.), and the bacteria from the plate were then divided into groups according to the reactions which they produced in the litmus milk tubes. By using this method it was possible to divide the bacteria developing on a plate into five groups, namely, the acid-forming and coagulating, the acid-forming, the inert which produce no change in milk, the alkali-forming, and the peptonizing groups. The acid-coagulating and the acid-forming groups are not necessarily composed of distinct organisms, although the acid-coagulating group probably included organisms which always coagulate milk, and in the acid group there are undoubtedly bacteria which never coagulate milk. The bacteria were divided by the reaction in litmus milk after incubation for 14 days at 30° C. (86° F.). It is impossible by the ordinary method of plating on litmus lactose gelatin to separate the alkali-forming bacteria from those which are inert on gelatin on account of the fact that colonies of alkali-forming bacteria on litmus lactose gelatin plates do not form enough alkali to produce a change of the litmus. The alkali and inert groups must then be classed together and also include acid-forming bacteria which do not produce enough acid to give a red coloration on the plate.

In order to show the value of the tube method a comparison with the plate method was made. Four different samples of milk were used, a portion of each being heated to 60° C. (140° F.) and also 65.6° C. (150° F.). The pasteurized milk was then plated on litmus lactose gelatin plates which were incubated at 18° C. (64.4° F.) for six days. A differential count was then made of the acid-forming, alkali or inert, and the peptonizing colonies. After counting, the colonies were picked off and inoculated into litmus milk in order to complete the milk-tube method. The results of the experiments are shown in Table 10. It may be plainly seen that the plate method was very inaccurate. The percentage of the acid group of bacteria was always increased by the milk-tube method of differentiation, and the alkali or inert groups were decreased.

TABLE 10.—*Comparison of the milk-tube and plate methods for the determination of the bacterial groups in milk.*

Sample No.	Temperature of heating.		Acid group.		Alkali or inert group.		Peptonizing group.	
			Milk-tube method.	Plate method.	Milk-tube method.	Plate method.	Milk-tube method.	Plate method.
	°C.	*°F.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
1	60.0	140	73.21	58.73	16.07	40.21	10.71	1.05
1	65.6	150	75.68	56.96	11.01	41.79	13.30	1.24
2	60.0	140	62.29	25.15	35.16	72.32	2.54	2.52
2	65.6	150	77.89	12.93	18.95	86.20	3.15	.86
3	60.0	140	58.39	34.35	32.83	58.77	8.75	6.87
3	65.6	150	94.36	45.68	4.83	52.15	.80	2.15
4	60.0	140	92.17	56.37	7.25	42.64	.56	.98
4	65.6	150	90.64	49.41	7.20	50.58	2.15	....

Usually the peptonizing group of bacteria was also increased. The differences in the differentiation of the bacterial groups is shown graphically in figure 4. The bacterial flora of four samples of milk pasteurized at 60° C. (140° F.) as shown by averages and determined by the plate method consisted of 43.65 per cent of the acid group, 53.48 per cent of alkali or inert group, and 2.85 per cent of the peptonizing group. When determined by the milk-tube method the group percentages were changed to 71.51 per cent of the acid group, 22.83 per cent of the alkali or inert group, and 5.64 per cent of the peptonizing group.

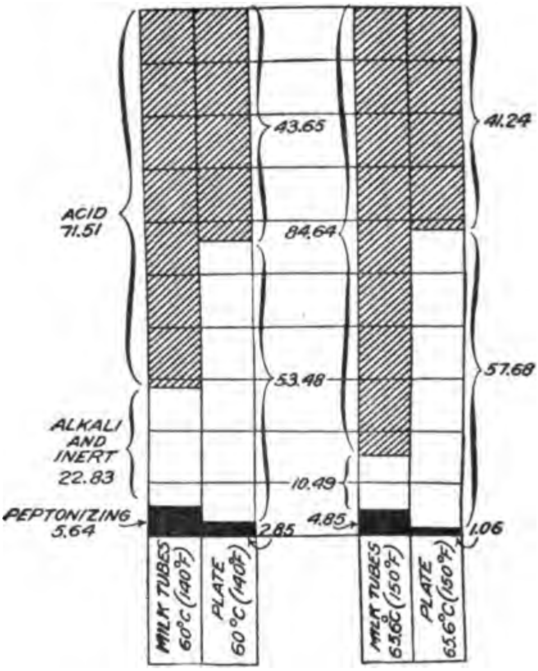

FIG. 4.—Comparison of the milk-tube and plate method for the determination of the bacterial groups in milk.

When milk was pasteurized at 65.6° C. (150° F.) there were marked differences in the bacterial flora when determined by the two methods (see fig. 4). The results from four samples were averaged. As determined by the plate method the bacterial flora consisted of 41.24 per cent of the acid group, 57.68 per cent of the alkali or inert group, and 1.06 per cent of the peptonizing group. When determined by the milk-tube method the percentages were changed to 84.64 per cent of the acid group, 10.49 per cent of the alkali or inert group, and 4.85 per cent of the peptonizing group. It is evident from these experiments that the milk-tube method was much superior to the litmus lactose gelatin plate method of differentiation. Its advantages may be summarized as follows:

1. The milk-tube method is more accurate than the plate method for the differentiation of bacteria into groups.
2. It is possible by this method to separate the alkali-forming group of bacteria from the inert group, which is not possible on litmus lactose gelatin plates.
3. The activity of the bacteria in the various groups can to some extent be determined by their ability to produce changes in litmus milk after various lengths of incubation.

THE BACTERIAL GROUPS IN GRADE A MILK BEFORE AND AFTER PASTEURIZATION FOR 30 MINUTES AT 62.8° C. (145° F.).

Throughout the study of the bacterial groups in raw and pasteurized milk the milk-tube method of differentiation has been used. The plating was on infusion agar, which was incubated for six days at 30° C. (86° F.). The milk used in the first experiments was of poor quality and constitutes grade A milk. Pasteurization was performed in sterile flasks and heated in a water bath for 30 minutes at 62.8°C. (145°F.). The percentage of the different bacterial groups was determined before and after pasteurization of the milk. In order to show the results in the most simple manner the group percentages of 10 samples of raw milk and 12 of pasteurized milk have been averaged and are shown graphically in figure 5. The average of the total acid group in raw milk was 46.88 per cent of the total bacteria. After pasteurization the percentage was increased to 79.78 per cent. The acid coagulating group was decreased from 36.17 per cent to 17.91 per cent. The inert group was also decreased and the alkali group slightly increased, from 6.47 per cent to 9.77 per cent, which was due to the averaging of one sample of pasteurized milk which was exceptionally high in the percentage of the alkali formers. The peptonizing group was decreased from 17.31 per cent in the raw milk to 1.39 per cent in the pasteurized milk. These results are most striking in so far that they are contrary to the most generally accepted ideas of the effect of pasteurization on the bacterial flora of milk.

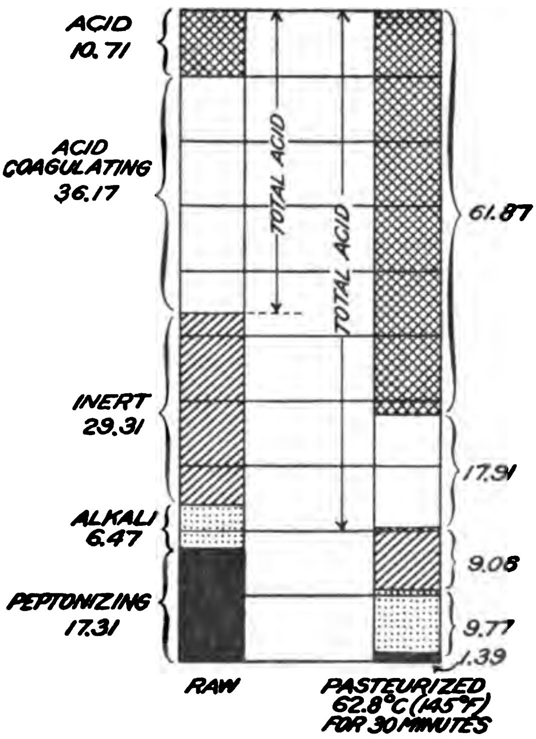

FIG. 5.—Bacterial groups of grade A milk before and after pasteurization for 30 minutes at 62.8° C. (145° F.).

THE BACTERIAL GROUPS IN GRADE A MILK BEFORE AND AFTER PASTEURIZATION FOR 30 MINUTES AT 71.1° C. (160° F.).

A second set of experiments was made, using grade A milk which was pasteurized at 71.1° C. (160° F.) for 30 minutes and examined in the same manner as before. The averaged results of five samples of raw and six samples of pasteurized milk are shown in figure 6. The changes in the bacterial groups were about the same as at 62.8° C. (145° F.). While the percentage of the total acid group was higher than in the milk pasteurized at the lower temperatures, it will be seen that the percentage of the acid-coagulating group was smaller. The acid group was made up largely of slow acid-forming organisms, as will be shown later. The alkali group was reduced and the peptonizing group reduced from 16.26 per cent in the raw to 0.53 per cent in the pasteurized milk.

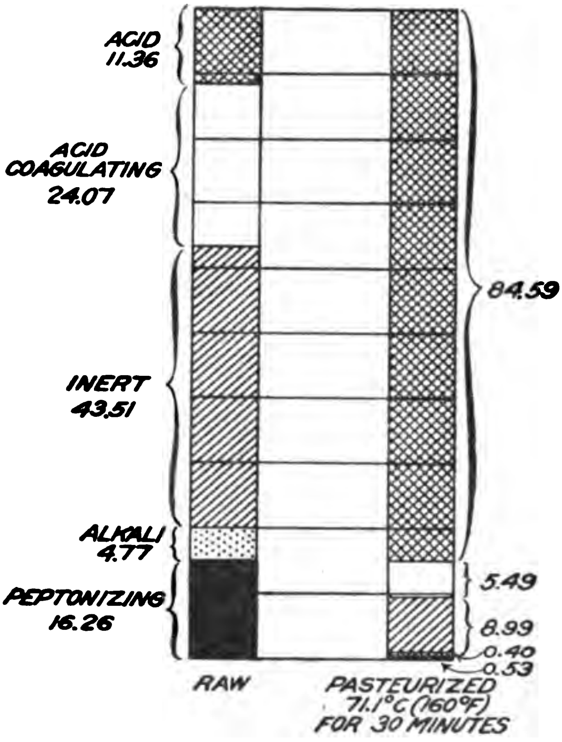

FIG. 6.—Bacterial groups in grade A milk before and after pasteurization for 30 minutes at 71.1° C. (160° F.).

THE BACTERIAL GROUPS IN GRADE B MILK BEFORE AND AFTER PASTEURIZATION FOR 30 MINUTES AT 62.8° C. (145° F.).

The same experiments were repeated, pasteurizing a better quality of milk, grade B, at 62.8° C. (145° F.). The averaged results of 17 samples of raw and 20 samples of pasteurized milk are shown in figure 7. The total acid group was increased from 22.72 per cent in the raw to 66.76 per cent in the pasteurized milk. It will be noticed that the acid-coagulating group was increased from 12.98 per cent to 31.89 per cent in the pasteurized milk. The alkali and peptonizing groups were reduced from 19.66 per cent to 5.63 per cent and from 14.10 to 3.59 per cent, respectively.

THE BACTERIAL GROUPS IN GRADE C MILK BEFORE AND AFTER PASTEURIZATION FOR 30 MINUTES AT 62.8° C. (145° F.).

A third grade of milk of good quality, grade C, was studied in the same manner as the other grades. The percentage of the various bacterial groups changed in a similar manner as in the other experiments. The milk was pasteurized for 30 minutes at 62.8° C. (145° F.). Figure 8 shows the averaged results. It may be seen that again the total acid group was increased in percentage from 40.70 per cent to 73.10 per cent of the total bacteria. The acid-coagulating group, however, decreased in percentage from 33.85 per cent to 11.85 per cent. All the other groups were decreased in their percentage by pasteurization. These results show that instead of the acid-forming bacteria being destroyed by pasteurization they were actually increased in their percentage of the total bacteria surviving the process. This does not mean that there were greater numbers of acid-forming bacteria after pasteurization but merely that a greater percentage of the bacteria in pasteurized milk were of the acid-forming group than in the milk before heating. The percentage of the other groups was lowered by pasteurization. This is of particular interest in the case of the peptonizing group, which has been believed to constitute the majority of the bacteria which survive the heating process. It must be remembered that these results apply for the most part to milk pasteurized at 62.8° C. (145° F.), although they hold for the few samples studied which were heated at 71.1° C. (160° F.). So far as the practical side is concerned, only the results at 62.8° C. (140° F.) are of value, for the higher temperatures are seldom used in commercial work.

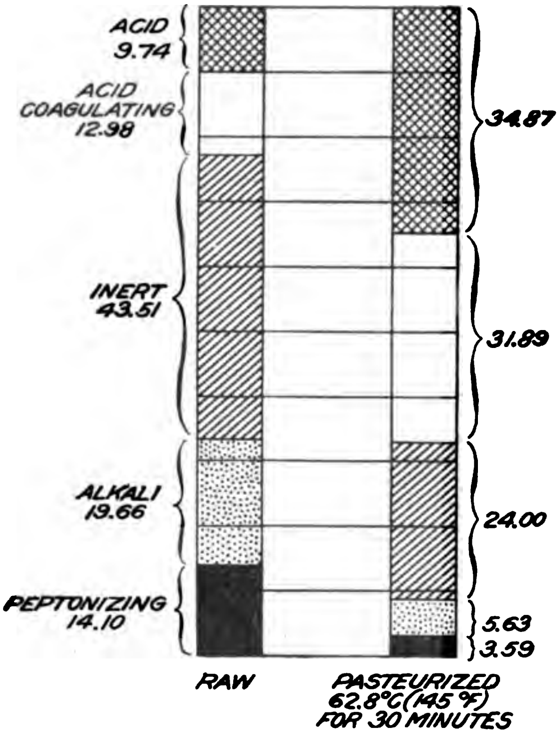

FIG. 7.—Bacterial groups in grade B milk before and after pasteurization for 30 minutes at 62.8° C. (145° F.).

THE BACTERIAL GROUPS IN MILK PASTEURIZED AT HIGH TEMPERATURES.

In order to determine the bacteria which survive pasteurization at high temperatures, the bacterial groups were determined by the milk-tube method in seven samples of milk. Two samples were pasteurized at 76.7° C. (170° F.), three at 82.2° C. (180° F.), one at 87.8° C. (190° F.), and two at 93.3° C. (200° F.). All were heated in sterile flasks and the temperatures held for 30 minutes. The percentages of the bacterial groups have been averaged at each temperature and are shown in figure 9. It will be seen that even at 76.7° C. (170° F.) a large percentage of the acid-forming group was found, the percentage of the total acid-forming group, including both the acid-coagulating and the simple acid-forming group, being 80.91 per cent. The bacteria of this group, however, produced acid very slowly, which differentiates them from those which survive at lower temperatures. An increase in the percentage of the peptonizing group over that at the lower temperatures is noticeable. The average percentage of the peptonizing group at 62.8° C. (145° F.) ranged from 1.39 per cent to 4.47 per cent in three grades of milk. At 71.1° C. (160° F.) the percentage was 0.53 per cent, while at 76.7° C. (170° F.) it was increased to 7.25 per cent. The increase is of course produced by the greater destruction of the other groups. At 82.2° C. (180° F.) a distinct change took place in percentage of the groups which survived the heating. The acid group was reduced greatly, while the peptonizing group was increased to 68.12 per cent of the total bacteria. The alkali group comprised 16.08 per cent of the bacteria, which is evidently a very high average. If a large number of samples had been studied, the average percentage of the

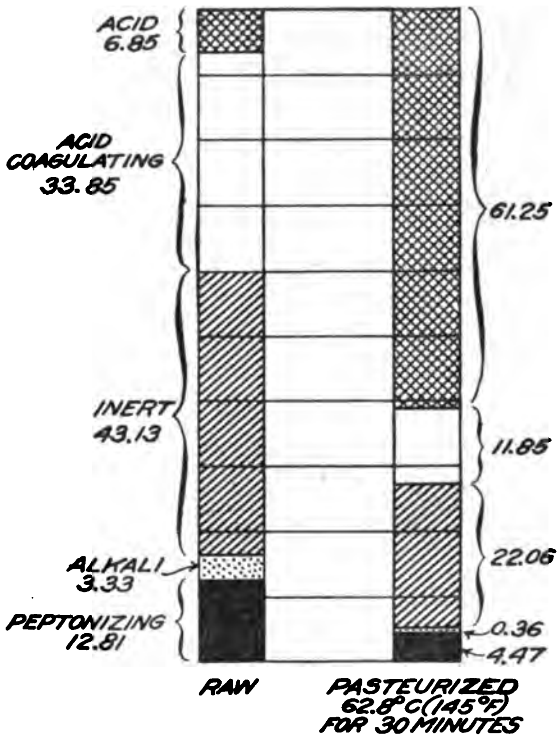

FIG. 8.—Bacterial groups in grade C milk before and after pasteurization for 30 minutes at 62.8° C. (145° F.).

group would have probably been very low, since at 71.1° C. (160° F.) and 76.7° C. (170° F.) only a very small percentage survived. The bacterial groups at the higher temperatures were similar to those at 82.2° C. (180° F.). The almost total absence of the acid-coagulating group and the low percentage of the acid group, together with the high percentage of the peptonizing group, is very noticeable.

THE ACTIVITY OF BACTERIA OF THE VARIOUS GROUPS ISOLATED FROM RAW AND PASTEURIZED MILK MEASURED BY THEIR ABILITY TO PRODUCE CHANGES IN LITMUS MILK AFTER DIFFERENT LENGTHS OF INCUBATION.

The activity of the bacteria found in raw and pasteurized milk is important since acid-forming bacteria which coagulates milk in 48 hours produce a more normal souring in pasteurized milk than the slow acid-producing forms which may be overgrown by the peptonizing bacteria. Organisms of the peptonizing group which cause peptonization rapidly are of far greater importance than those which require long incubation to produce changes in milk. During the determination of the bacterial groups by the milk-tube method the reactions produced by the different cultures of bacteria were recorded after 2, 5, and 14 days' incubation. The length of time required to produce changes in litmus milk served as a measure of the activity of the culture. It then follows that the changes in the group relations as determined by the litmus milk tube reactions gave a general indication of the activity of the bacteria which composed the group.

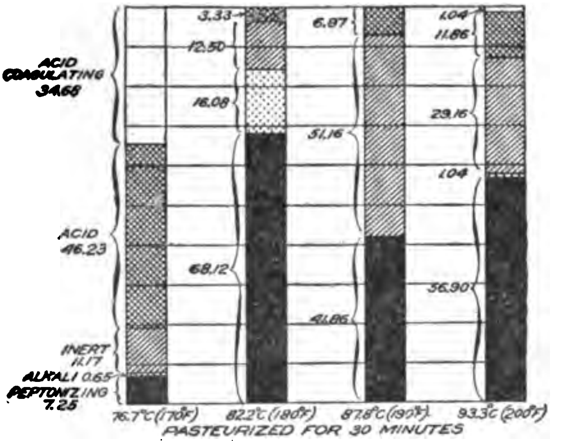

FIG. 9.—Bacterial groups which survive pasteurization for 30 minutes at 76.7° C. (170° F.), 82.2° C. (180°F.), 87.8 C. (190° F.), and 93.3° C. (200° F.).

The activity of bacteria of the various groups isolated from three grades of milk has been studied.

GRADE A MILK BEFORE AND AFTER PASTEURIZATION AT 62.8° C. (145° F.) FOR 30 MINUTES.

The results shown in Table 11 indicate the rapidity of the growth of the bacteria of the various groups isolated from milk before and after pasteurization at 62.8° C. (145° F.) as measured by their ability to produce a change in litmus milk. As may be noted from the table, plates were made of infusion and casein agar and the colonies developing on each medium were picked off and differentiated by the tube method. The group percentages in the table represent the average of a number of samples. In general it may be said that casein agar seemed to favor the growth of the alkali forming and the peptonizing bacteria so that their group percentages were usually higher when determined on that medium. In order to show the results more plainly the averages have been plotted as shown in figure 10. The blocks in the columns represent the bacterial group percentages determined by the tube method after 2, 5, and 14 days' incubation in milk. The column at 2 days, for example, shows the group percentages determined by the reactions of the colonies picked from an infusion agar plate. The percentages were determined by the reactions of the milk tubes after 2 days' incubation at 30° C. (86° F.). The tubes were then incubated for 3 days more and the group percentages again determined by the reactions. Incubation was then continued for 14 days, when the final reactions were recorded. The figure shows that the percentage of the total acid group was greater in raw milk after two days' incubation than in pasteurized. After five days, however, the total acid group was higher in percentage in pasteurized milk. After 14 days the total acid group in pasteurized milk was much larger. This shows that the bacteria of the acid group in pasteurized milk develop slower, or at least produce acid slower, than those in raw milk. Since the differentiation of the groups was based on the change produced in litmus milk by the bacteria, it may be seen from the figure that as a rule the alkali-forming bacteria did not develop enough alkali to change the color of litmus, which differentiates them as belonging to the alkali group, until the fifth day of incubation. While the figure may seem rather complicated, a careful study clearly shows the difference in the bacterial groups in raw and pasteurized milk based on the rapidity with which they produce changes in litmus milk.

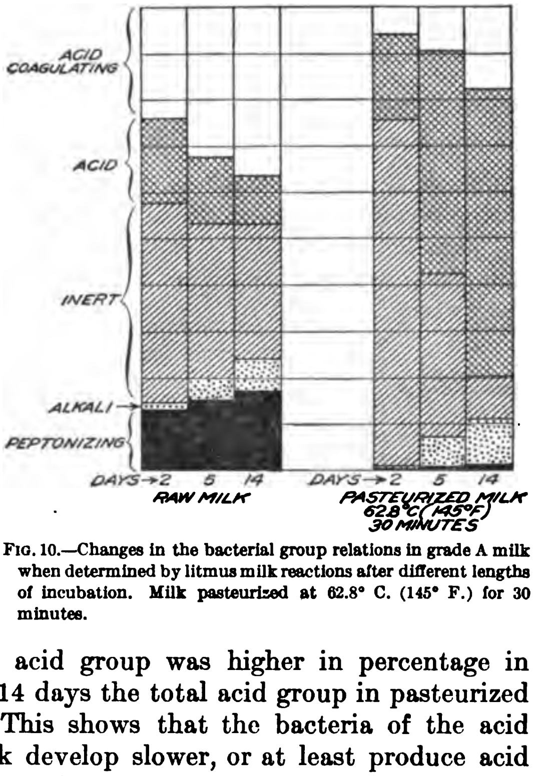

FIG. 10.—Changes in the bacterial group relations in grade A milk when determined by litmus milk reactions after different lengths of incubation. Milk pasteurized at 62.8° C. (145° F.) for 30 minutes.

TABLE 11.—*Changes in the bacterial group relations in grade A milk when determined by litmus milk reactions after different lengths of incubation—Milk pasteurized at 62.8° C. (145° F.) for 30 minutes.*

Bacterial groups.	Infusion agar plates.						Casein agar plates.					
	Raw milk.			Pasteurized milk.			Raw milk.			Pasteurized milk.		
	2 days.	5 days.	14 days.	2 days.	5 days.	14 days.	2 days.	5 days.	14 days.	2 days.	5 days.	14 days.
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Acid coagulating	24.18	32.72	36.17	6.01	9.52	17.91	7.89	16.96	19.51	2.42	4.34	15.12
Acid............	18.08	14.64	10.71	19.01	48.01	61.87	15.13	14.34	12.12	11.63	42.17	51.95
Inert............	42.94	33.23	29.31	74.69	35.13	9.06	62.26	45.95	32.99	85.80	48.67	15.98
Alkali...........	1.29	4.02	6.47	.02	6.55	9.77	.70	5.69	17.58	......	4.17	15.73
Peptonizing.....	13.47	15.37	17.31	.26	.77	1.39	13.99	17.04	17.77	.12	.62	1.20
Total.....	99.96	99.98	99.97	99.99	99.98	100.00	99.97	99.98	99.97	99.97	99.97	99.98
Number of samples averaged..	10	10	10	12	12	12	7	7	7	10	10	10

GRADE A MILK BEFORE AND AFTER PASTEURIZATION FOR 30 MINUTES AT 71.1° C. (160° F.).

Earlier in this paper it was shown that the percentage of the total acid group was higher in grade A milk pasteurized at 71.1° C. (160° F.) than at 62.8° C. (145° F.). It is natural to suppose, then, that milk pasteurized at the higher temperatures would sour more quickly than when heated at the lower temperatures. Such is not the case, however; first, because the total number of bacteria are less in the milk pasteurized at 71.1° C. (160° F.), and, second, because the acid group of bacteria is less active. This last reason is shown by the changes in the bacterial group relations as determined in litmus milk by different lengths of incubation. Table 12 shows the averaged group percentages determined from infusion and casein agar plates. The results are shown to better advantage in figure 11. It will be noticed that after two days' incubation only a small percentage of acid-forming bacteria were recorded in the pasteurized milk and none of the acid-coagulat-

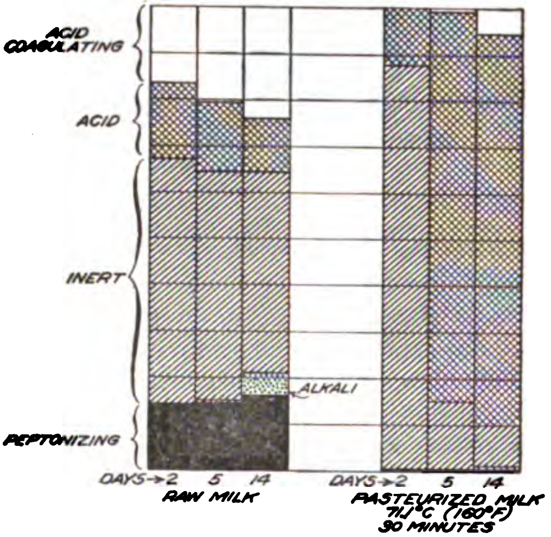

FIG. 11.—Changes in the bacterial group relations in grade A milk when determined by litmus milk reactions after different lengths of incubation. Milk pasteurized at 71.1° C. (160° F.) for 30 minutes.

ing group. After five days the acid group was increased greatly, but there was only an extremely small percentage of the acid-coagulating group. Even after 14 days' incubation the reactions showed only a small percentage of the acid-coagulating group. In both raw and pasteurized milk the slow growth of the alkali group is shown by the fact that only a small percentage was found in the raw milk after five days' incubation of the litmus milk tubes, while none was found in the pasteurized milk until after 14 days' incubation.

TABLE 12.—*Changes in the bacterial group relations in grade A milk when determined by litmus milk reactions after different lengths of incubation—Milk pasteurized at 71.1° C. (160° F.) for 30 minutes.*

Bacterial groups.	Infusion agar plates.						Casein agar plates.					
	Raw milk.			Pasteurized milk.			Raw milk.			Pasteurized milk.		
	2 days.	5 days.	14 days.	2 days.	5 days.	14 days.	2 days.	5 days.	14 days.	2 days.	5 days.	14 days.
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Acid coagulating	16.58	20.22	24.07	....	0.17	5.49	12.47	16.49	17.50	....	....	10.88
Acid	16.35	14.60	11.36	12.03	85.29	84.59	10.65	6.44	7.22	7.67	70.10	63.44
Inert	52.95	49.51	43.51	87.56	14.14	8.99	64.30	58.85	47.28	92.26	29.53	24.93
Alkali	....	.89	4.77	....	....	.40	.13	2.43	10.06	....	....	....
Peptonizing	14.11	14.76	16.26	.39	.39	.53	12.43	15.77	17.92	.06	.36	.70
Total	99.99	99.98	99.97	99.98	99.99	100.00	99.98	99.98	99.98	99.99	99.99	99.95
Number of samples averaged.	5	5	5	6	6	6	9	9	9	11	11	11

GRADE B MILK BEFORE AND AFTER PASTEURIZATION FOR 30 MINUTES AT 62.8° C. (145° F.)

The changes in the bacterial group relations determined by the milk-tube method after various lengths of incubation showed a difference from those in grade A milk. Table 13 shows the averages of the group percentages which are plotted in figure 12. A study of the plot shows that the percentage of the total acid group and the acid-coagulating group itself was greater in the pasteurized milk after the two days' incubation period than in the raw milk. In other words, the activity of the acid-producing organisms which survived the heating was as great as those in raw milk. The reason for the difference in the two grades of milk is not apparent.

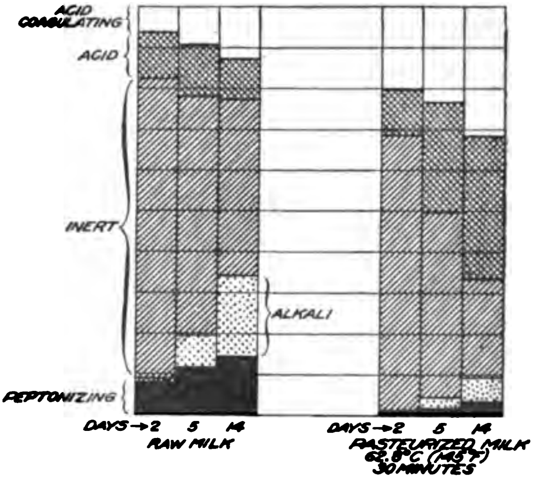

FIG. 12.—Changes in the bacterial group relations in grade B milk when determined by litmus milk reactions after different lengths of incubation.

TABLE 13.—*Changes in the bacterial group relations in grade B milk when determined by litmus milk reactions after different lengths of incubation—Milk pasteurized at 62.8° C. (145° F.) for 30 minutes.*

Bacterial groups.	Infusion agar plates.						Casein agar plates.					
	Raw milk.			Pasteurized milk.			Raw milk.			Pasteurized milk.		
	2 days.	5 days.	14 days.	2 days.	5 days.	14 days.	2 days.	5 days.	14 days.	2 days.	5 days.	14 days.
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Acid coagulating	6.59	9.54	12.98	20.05	23.12	31.89	6.14	7.66	8.45	10.58	12.86	18.73
Acid	11.39	12.55	9.74	11.27	27.48	34.87	4.67	5.17	7.18	6.72	27.98	29.72
Inert	73.45	58.04	43.51	67.46	45.02	24.00	81.37	66.89	50.09	82.30	55.84	40.63
Alkali	.21	7.86	19.66	....	2.39	5.63	.09	6.53	17.79	.03	2.43	7.92
Peptonizing	8.35	11.99	14.10	1.21	1.98	3.59	7.69	13.73	16.47	.35	.87	2.99
Total	99.99	99.98	99.99	99.99	99.99	99.98	99.96	99.98	99.98	99.98	99.98	99.99
Number of samples averaged	16	17	17	19	20	20	17	18	18	21	22	22

GRADE C MILK BEFORE AND AFTER PASTEURIZATION FOR 30 MINUTES AT 62.8° C. (145° F.)

When grade C milk was studied in the same manner, the percentage of the acid-coagulating group in pasteurized milk was found to be small and the group inactive. The averaged results in Table 14, and shown graphically in figure 13, bring out this point. It will be seen that the acid-coagulating group percentage was very small up to the 14 days' incubation period. The acid group also was rather inactive as indicated by the percentages. A large part of the peptonizing group developed slowly, as indicated by the increase in the percentage of groups shown in the various plots.

TABLE 14.—*Changes in the bacterial group relations in grade C milk when determined by litmus milk reactions after different lengths of incubation—Milk pasteurized at 62.8° C. (145° F.) for 30 minutes.*

Bacterial groups.	Infusion agar plates.						Casein agar plates.					
	Raw milk.			Pasteurized milk.			Raw milk.			Pasteurized milk.		
	2 days.	5 days.	14 days.	2 days.	5 days.	14 days.	2 days.	5 days.	14 days.	2 days.	5 days.	14 days.
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Acid coagulating	18.10	31.33	33.85	0.06	0.35	11.85	7.25	9.96	9.90	0.36	0.36	3.19
Acid	15.18	9.42	6.85	6.82	43.02	61.25	5.59	7.17	7.94	1.96	19.84	34.57
Inert	64.54	49 44	43.13	91.21	53.46	22.06	84.53	76.09	63.79	93.02	71.53	49.74
Alkali	.20	1.66	3.33	....	.06	.36	....	1.11	5.90	....	.90	2.99
Peptonizing	1.96	8.13	12.81	1.89	3.09	4.47	2.61	5.65	12.44	4.65	7.35	9.49
Total	99.98	99.98	99.97	99.98	99.98	99.99	99.98	99.98	99.97	99.99	99.98	99.98
Number of samples averaged	12	12	12	11	11	11	9	9	9	11	11	11

It is interesting to note the activity of the total acid group in pasteurized milk of grade B, and although the average bacterial count was high this grade of milk more nearly represents the ordinary quality of milk which is pasteurized commercially than either grades A or C.

COMPARISON OF THE PERCENTAGE OF ACID-FORMING BACTERIA IN RAW AND PASTEURIZED MILK.

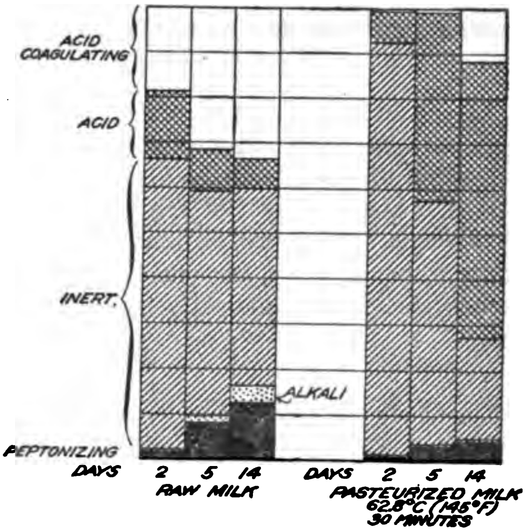

FIG. 13.—Changes in the bacterial group relations in grade C milk when determined by litmus milk reactions after different lengths of incubation.

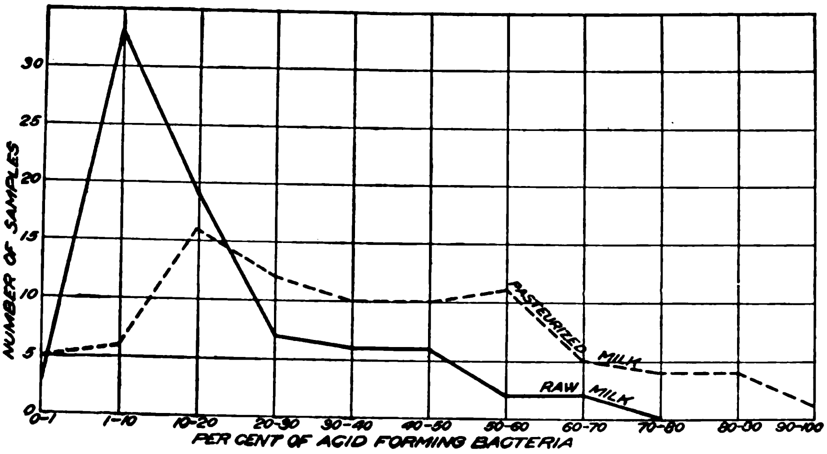

FIG. 14.—Comparison of the percentage of the acid-forming bacteria in raw and pasteurized milk.

As has already been shown, the acid bacteria instead of being destroyed by pasteurization for 30 minutes at 62.8° C. (145° F.) are actually increased in their percentage of the total bacteria. The large percentage of the acid group which survive the process are shown in the frequency curve in figure 14. The number of samples were plotted as ordinates and the percentage of the acid-forming bacteria as abscissæ, the ranges in percentages from 0–1, 1–10, 10–20, etc., being taken as points. Thirty-nine samples of raw and 42 of pasteurized milk were examined. The samples of milk were pasteurized for 30 minutes at 62.8° C. (145° F.). It will be seen from the figure that with the raw milk the peak of the curve is at 1–10, while one peak of the curve of pasteurized milk is at 10–20 and another at 50–60. In other words, the majority of the samples of raw milk contained from 1 to 10 per cent of bacteria of the acid group. The number of samples containing higher percentages gradually diminished until no sample contained over 80 per cent. Among the samples of the pasteurized milk, it may be seen from the curve that the majority of them contained from 10 to 60 per cent of the acid group and some samples as high as 90 per cent.

COMPARISON OF THE PERCENTAGE OF PEPTONIZING BACTERIA IN RAW AND PASTEURIZED MILK.

In the same manner 39 samples of raw milk and 42 samples of milk pasteurized for 30 minutes at 62.8° C. (145° F.) have been grouped according to the percentage of peptonizing bacteria which they contained. A comparison of the frequency curves in figure 15 shows that the pasteurized milk contained a lower percentage of the peptonizing group than did the raw milk. A large number of samples of pasteurized milk contained between 0 and 1 per cent of peptonizing bacteria, while only one sample of raw milk contained that low percentage. The same number of samples of both raw and pasteurized milk contained from 1 to 10 per cent. It will also be seen from the curve that a few samples of both raw and pasteurized milk contained higher than 1 to 10 per cent of the peptonizing group. However, in a comparison of the raw and pasteurized milk it was found that a larger number of samples of raw milk contained the high percentages of peptonizers.

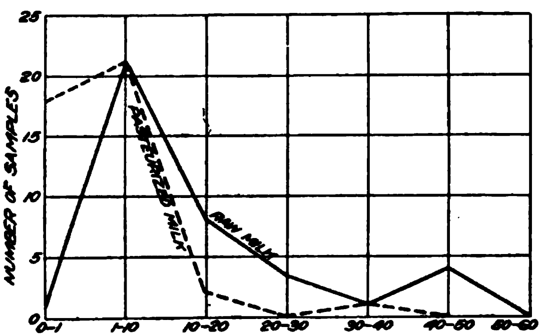

FIG. 15.—Comparison of the percentage of the peptonizing bacteria in raw and pasteurized milk.

AVERAGE PERCENTAGES OF THE BACTERIAL GROUPS OF RAW MILK WHICH SURVIVE PASTEURIZATION.

The effect of pasteurization upon the bacteria in milk may be shown by a determination of the percentage of the bacterial groups of raw milk which are found after heating. This percentage was obtained by subtracting the percentage reduction by pasteurization of the various groups from 100 per cent. The samples of raw and pasteurized milk were plated on infusion and casein agar and the percentage reduction of the various groups determined by the milk tube method. Table 15 shows the averaged results from infusion and casein agar plates, using three grades of milk for examination.

It may be seen that a greater percentage of the acid group of bacteria in the raw milk remained after heating than any of the other groups. As a rule a smaller percentage of the peptonizing group survived than either of the other groups. In general the result when casein agar was used was higher, although the reason is not apparent.

Table 15.—*Average percentages of the bacterial groups of raw milk which survive pasteurization by the "holder" process.*

Pasteurization temperature.	Media.	Bacterial groups.			
		Acid.	Inert.	Alkali.	Peptonizing.
Grade A, 62.8° C. (145° F.)	Infusion agar	1.27	0.37	0.05	0.06
	Casein agar	4.26	.31	1.55	.08
Grade A, 71.1° C. (160° F.)	Infusion agar	1.71	.12	.10	.01
	Casein agar	2.34	.39	0	.03
Grade B, 62.8° C. (145° F.)	Infusion agar	6.98	1.48	1.27	1.86
	Casein agar	6.50	2.06	2.05	.51
Grade C, 62.8° C. (145° F.)	Infusion agar	4.55	1.59	.19	1.24
	Casein agar	13.09	4.49	1.13	1.25

THE EFFECT OF PASTEURIZATION ON THE NUMBER OF BACTERIA OF DIFFERENT GROUPS IN MILK.

In order to show the effect of pasteurization on the numbers of the bacteria of different groups, Table 16 has been arranged. This shows the calculated number of bacteria in each group determined from the average total counts on infusion agar and the group percentages as shown by the milk-tube method. To illustrate this further take the samples from dairy A, as shown in Table 16. The bacterial count of 12 samples of raw milk averaged was 21,100. The averaged group percentages of the 12 samples was 33.85 per cent of the acid-coagulating group, 6.85 per cent of the acid group, and so on. The acid-coagulating group contained on an average 33.85 per cent of the average total count, or approximately 7,160 bacteria per cubic centimeter. The other bacterial numbers were calculated in the same way.

TABLE 16.—*Comparison of the number of bacteria of different groups in milk before and after pasteurization.*

Average total count per cubic centimeter.	Average group percentage.	Group.	Calculated number of each group per cubic centimeter.
Raw milk, 21,100. Average of 12 samples. Dairy A.	33.85	Acid-coagulating	7,160
	6.85	Acid	1,450
	43.13	Inert	9,120
	3.33	Alkali	705
	12.81	Peptonizing	2,700
Pasteurized milk, 62.8° C. (145° F.), 30 minutes, 420. Average of 11 samples. Dairy A	11.85	Acid-coagulating	50
	61.25	Acid	257
	22.06	Inert	92
	.36	Alkali	2
	4.47	Peptonizing	19
Raw milk, 2,840,000. Average of 17 samples. Dairies B and C	12.98	Acid-coagulating	368,800
	9.74	Acid	276,700
	43.51	Inert	1,236,000
	19.66	Alkali	558,000
	14.10	Peptonizing	400,000
Pasteurized milk, 62.8° C. (145° F.), 30 minutes, 11,700. Average of 20 samples. Dairies B and C	31.89	Acid-coagulating	3,760
	34.87	Acid	4,110
	24.00	Inert	2,830
	5.63	Alkali	660
	3.59	Peptonizing	420
Raw milk, 22,800,000. Average of 10 samples. Dairy D	36.17	Acid-coagulating	8,200,000
	10.71	Acid	2,450,000
	29.31	Inert	6,700,000
	6.47	Alkali	1,480,000
	17.31	Peptonizing	3,900,000
Pasteurized milk, 62.8° C. (145° F.), 30 minutes, 83,000. Average of 12 samples. Dairy D	17.91	Acid-coagulating	14,900
	61.87	Acid	51,500
	9.06	Inert	7,500
	9.77	Alkali	8,130
	1.39	Peptonizing	1,150

The most striking features of the table is the high number of acid-forming bacteria in proportion to the low number of peptonizers in the pasteurized milk and the marked difference in the numbers of peptonizing bacteria before and after pasteurization. The milk from dairy A was exceptionally good, the average total count of the raw milk being 21,100 and after pasteurization for 30 minutes at 62.8° C. (145° F.) only 420 per cubic centimeter. The peptonizers were reduced from 2,700 to 19 per cubic centimeter.

The milk from dairies B and C was of poorer quality, the average count of the raw milk being 2,840,000. After pasteurization the count was 11,700. The peptonizers were reduced by the process from 400,000 to 420 per cubic centimeter. In the last part of the table the results of the examination of poor milk is shown. The average count was 22,800,000 bacteria per cubic centimeter before and 83,000 after pasteurization for 30 minutes at 62.8° C. (145° F.). The raw milk contained an average of 3,900,000 peptonizers per cubic centimeter and after pasteurization only 1,150 per cubic centimeter. Throughout the whole series may be noticed the low number of alkali-forming bacteria in the pasteurized milk in proportion to those in the raw milk. After a comparison is made of the kinds of bacteria in the raw milk from dairies B and C and in the extremely poor milk from dairy D with the same milk after pasteurization there should be no question as to the beneficial effect of the process.

THE BACTERIAL DEVELOPMENT IN MILK PASTEURIZED IN THE LABORATORY AND HELD AT DIFFERENT TEMPERATURES.

After having determined the groups of bacteria which survived pasteurization, their subsequent development was traced in a few samples of milk.

The changes in the bacterial flora of milk pasteurized for 30 minutes at 62.8° C. (145° F.) during storage at different temperatures has been studied in a poor, medium, and good grade of milk. One sample of each grade of milk was divided and each part pasteurized in a sterile flask. After pasteurization each sample was held in the ice box at approximately 7.23° C. (45° F.) for 18 hours; then one flask was held at room temperature, the other was kept in the ice box. After pasteurization and on each successive day each sample was plated to determine the number of bacteria which were then differentiated by the milk-tube method. On account of the great amount of work involved and time consumed in determining the bacterial flora by the milk-tube method only one sample of each grade was studied.

TABLE 17.—*Daily changes in the bacterial groups of pasteurized milk held at different temperatures.*

Holding temperature.	Raw milk.	Pasteurized milk held—															
		0 day.	1 day.	2 days.	3 days.	4 days.	5 days.	6 days.	7 days.	8 days.	9 days.	10 days.	11 days.	12 days.	13 days.	14 days.	15 days.
SAMPLE G.																	
Room temperature.																	
Acid-coagulating	18.06		1.54	9.52	53.47												
Acid	10.28	85.71	66.15		.49												
Inert	38.94	4.76	7.69		23.76												
Alkali	.93	4.76	4.61	9.52	1.47												
Peptonizing	31.76	4.76	20.00	80.95	20.79												
Ice box, 10° C. (50° F.).																	
Acid-coagulating				11.32					6.12	2.97	11.07	14.89	11.52		18.00		
Acid		85.71		78.30	60.00	54.54		87.50	20.41	32.67	12.92	27.66	29.49		28.33		
Inert		4.76		4.72	10.00	18.18		12.50	36.73	18.81	40.30	52.12	46.54		41.33		
Alkali		4.76		5.66	30.00	9.09			32.65	41.58	28.00	5.31	11.06		11.00		
Peptonizing		4.76				18.18			4.08	3.96	7.92		1.38		1.33		
SAMPLE H.																	
Room temperature.																	
Acid-coagulating	17.96	32.06	35.05		67.05	71.66		89.50									
Acid	39.06	26.63	33.50		3.53	1.66		2.21									
Inert	10.93	10.32	6.70		17.64	20.00		3.31									
Alkali	13.28	30.43	24.74		11.76	6.66		4.97									
Peptonizing	18.75	.54															
Ice box, 10° C. (50° F.).																	
Acid-coagulating		32.06	43.57	37.62	36.36	21.74				1.55			10.00		32.12		
Acid		26.63	35.19	20.62	34.23	43.48		17.77	10.00	7.75		2.32	12.50		15.54		
Inert		10.32	2.79	15.97	3.74	8.69		6.66	24.00	25.58		4.64	2.50		14.51		
Alkali		30.43	18.43	25.78	24.59	26.08		68.88	66.00	62.79		93.02	75.00		37.30		
Peptonizing		.54			1.07			6.66		2.32					.52		
SAMPLE K.																	
Room temperature.																	
Acid-coagulating	46.15																
Acid	21.15	75.00	42.85														
Inert	26.92	25.00	57.14	100.00	40.00												
Alkali																	
Peptonizing	5.76				60.00	100.00											
Ice box, 10° C. (50° F.).																	
Acid-coagulating						66.66				7.69	52.17	2.66			11.11	16.25	7.39
Acid		75.00	54.54	66.66	50.00	33.33		50.00	50.00	30.77	26.08	40.00	68.18		35.55	17.50	22.66
Inert		25.00	45.45	33.33	50.00			50.00	50.00	61.53	21.74	57.33	31.81		33.33	33.75	58.12
Alkali															20.00	32.50	11.82
Peptonizing																	

The daily bacterial group percentages are shown in Table 17. The room temperature varied from 21.1°–23.9° C. (70°–75° F.) while the temperature of the ice box ranged from 8°–10° C. (46.4°–50° F.). The bacterial group percentages in each raw milk are shown followed by the "0" day determination which gives the group percentages immediately after pasteurization. Sample G represented a poor quality of milk, H a milk of medium quality, such as is usually commercially pasteurized, and sample K an excellent grade of milk containing only a few thousand bacteria per cubic centimeter. The samples of milk were pasteurized and held so as to prevent any possible reinfection. In order to show the changes in the groups more plainly, the results from Table 17 have been plotted. Figure 16 shows the changes in the bacterial flora of sample G held at room temperature. This sample showed a rennet curd on the third day. While there was a little acid development during the first three days, a rapid increase occurred from the third to the fourth day. From the figure it may be seen that there was a rapid increase in the percentage of the peptonizing group from 4.75 per cent on "0" day to 20 per cent after one

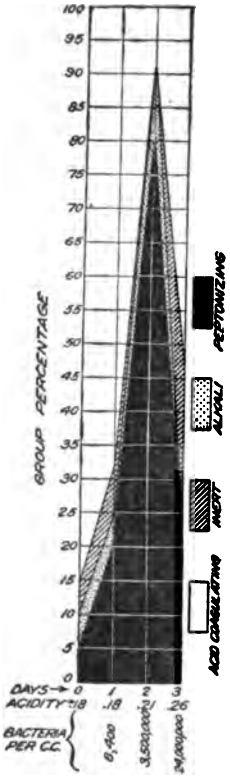

Fig. 16.—Daily changes in the bacterial group relations in pasteurized milk. Sample G held at room temperature.

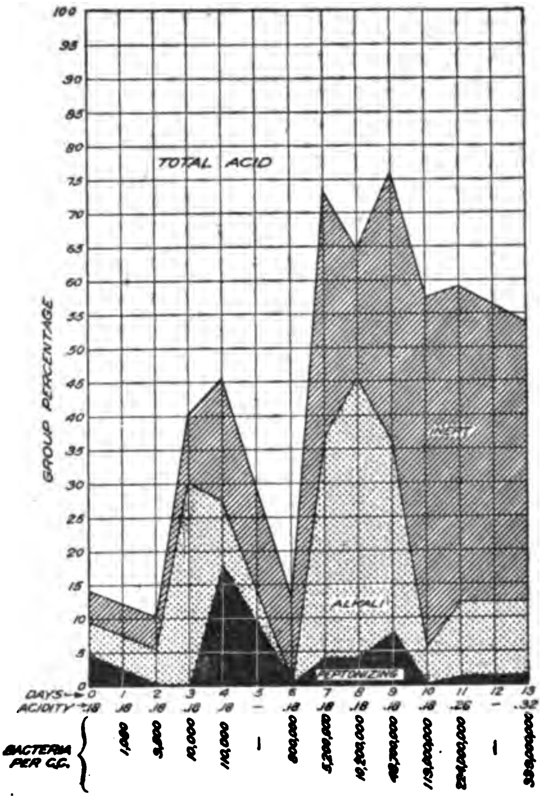

Fig. 17.—Daily changes in the bacterial group relations in pasteurized milk. Sample G held in the ice box.

day, then to 80.95 per cent after two days, followed by a drop to 20.79 per cent the third day. Corresponding to the increase in the proportion of the peptonizing group there was a decrease in the acid group followed by an increase on the third day. The acid group comprised 85.71 per cent of the bacteria at first, then dropped to 67.69 per cent after one day, then to 9.52 on the second day, then increased 53.96 per cent. The percentage of the alkali group throughout was low. As the plot shows, there was a rapid increase in the peptonizing bacteria which produced a rennet curd on the third day. Up to that time the development of the acid-forming bacteria was slow, and while there was some development of acid, apparently not enough was formed to check the development of the peptonizing group. To summarize, it may be said that in sample G, held at room temperature, there was a rapid growth of peptonizing organisms which produced a rennet curd, followed by acid development produced by the growth of the acid-forming bacteria.

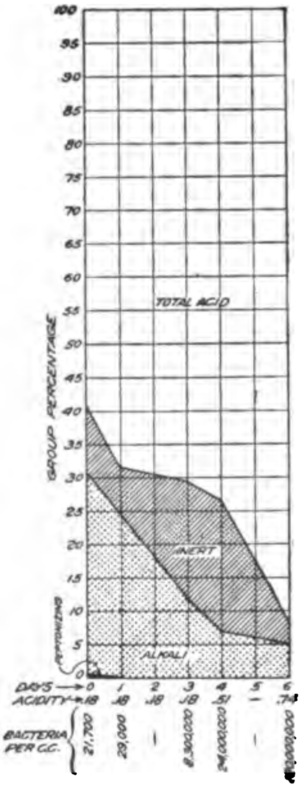

FIG. 18.—Daily changes in the bacterial group relations in pasteurized milk. Sample H held at room temperature.

The other portion of sample G was held in the ice box. Figure 17 shows the results graphically. It may be seen that there was only a slight acid development during the 13 days' holding period. The most striking point is the restriction of the development of the peptonizing group by the low temperature at which the sample was held. A comparison of the plot of the peptonizing group in figures 16 and 17 shows this point plainly. There was a slow bacterial development during the first six days as shown by the total counts. During that time the percentage of the acid group was high. From the seventh to the ninth day the per cent of the acid group was low, with a corresponding increase in the alkali and inert groups. From the ninth day the percentage of the acid group began to increase and the acidity also increased. The bacterial groups were not studied after the thirteenth day, but the sample was held and acidity was determined daily. It was found that the milk eventually soured. After eight days an old taste developed which would prevent its consumption as a food.

The changes in the bacterial flora of a better grade of milk represented by sample H were much different when the milk was held at room temperature. As may be seen from figure 18 the milk soured with a constantly increasing percentage of the acid group and decrease in the other group percentages. The percentage of the acid group increased from 58.69 after pasteurization to 91.71 after six days.

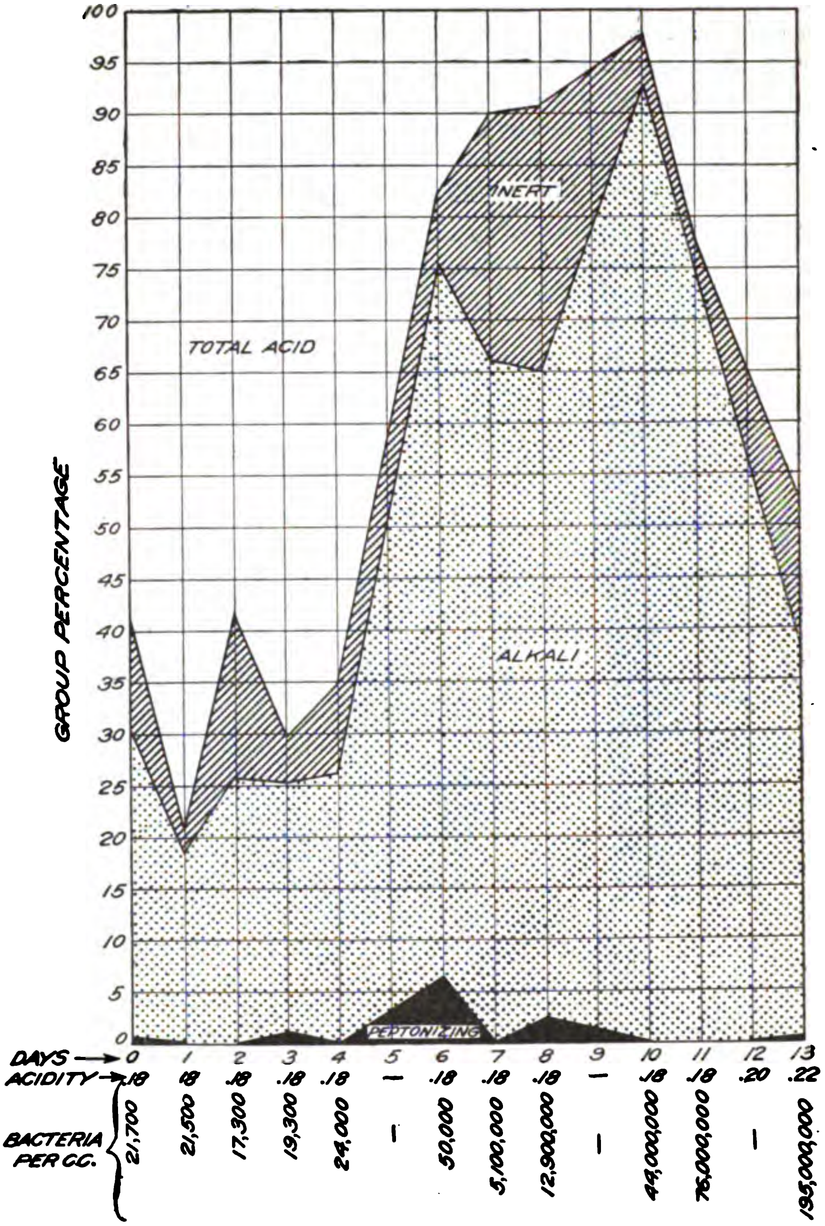

FIG. 19.—Daily changes in the bacterial group relations in pasteurized milk. Sample H held in ice box.

The percentage of the peptonizing group was 0.54 immediately after heating and none appeared in the plates in the later examinations.

The changes in the groups of the other portion of sample H held in the ice box are shown in figure 19. The development of the alkali group after four days is plainly shown. With the increase in the percentage of the alkali group there was a corresponding decrease in the acid group. After 10 days the percentage of the alkali group began to decrease and the acid group to increase. The percentage of the peptonizing group was low through the whole period. The acidity did not change until the twelfth day. After 11 days the milk had an old taste and would not be used.

The changes in the bacterial groups in the best grade of milk represented by sample K were different from the others when the milk was held at room temperature. After six days the milk was putrid and digested, but had not coagulated. As may be seen from figure 20, there was no acid formed. On the second day the peptonizing bacteria began to increase rapidly, and on the fourth day only organisms of the peptonizing group were found. The acid group gradually decreased until the second day, after which none appeared on the plates. The extreme changes in the group percentages were due to the low number of bacteria in the milk. When only a few colonies appeared on a plate the determination of the groups was of course,

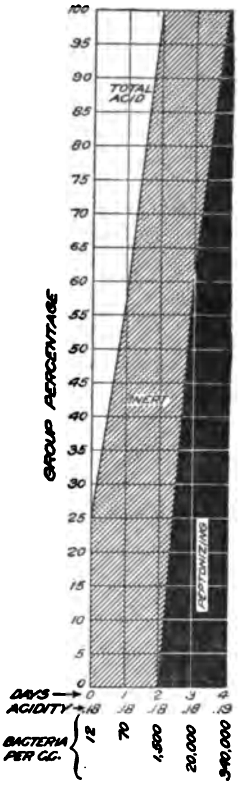

FIG. 20.—Daily changes in the bacterial group relations in pasteurized milk. Sample K held at room temperature.

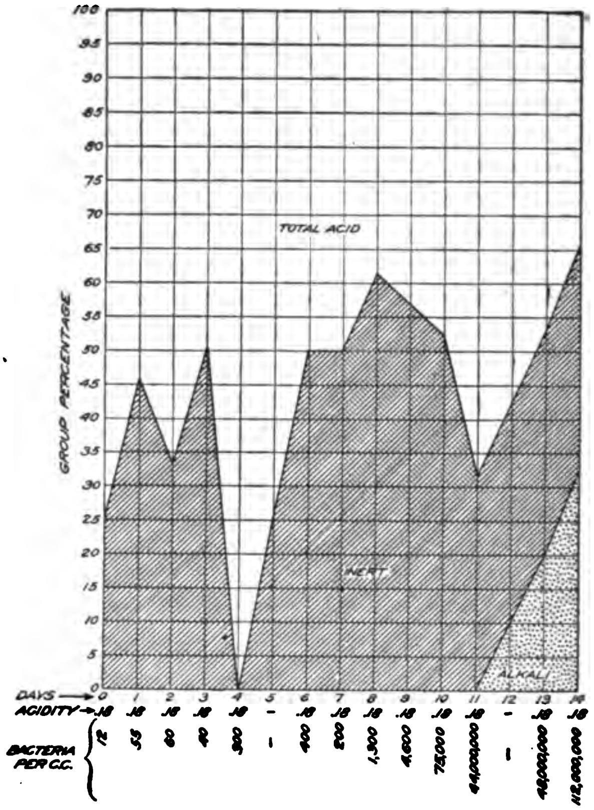

FIG. 21.—Daily changes in the bacterial group relations in pasteurized milk. Sample K held in the ice box.

much less accurate than when 100 or more colonies are studied by the milk-tube method.

The restraining effect of low temperatures on the development of the peptonizing group is again plainly shown in figure 21, which represents the bacterial group changes in the other portion of sample K held in the ice box. No peptonizing bacteria were found on the plates throughout the whole series and none of the alkali group appeared until the twelfth day. The acid group predominated throughout with considerable fluctuation due to inaccuracy on account of low bacterial numbers. The total counts were very low until the eleventh day, after which there was a rapid increase. After 17 days an old taste was noticed and at that time the acidity began to increase slowly.

These results are shown merely to indicate the possible changes which may take place in milk pasteurized in sealed bottles. It is clear that there is a delicate balance between the various bacterial groups which may be influenced by conditions of temperature and time so that various effects may be produced. These results can not be applied to commercial problems, since in laboratory experiments it is impossible to duplicate commercial conditions. In order to determine the changes in milk commercially pasteurized in sealed bottles a study must be carried on only under commercial conditions.

QUALITATIVE STUDY OF THE GROUPS OF BACTERIA WHICH SURVIVE PASTEURIZATION.

During the determination of the percentage of the bacterial groups cultures were selected for further study. These were selected from milk pasteurized at 62.8° C. (145° F.) for 30 minutes. The cultures were purified by plating, then examined microscopically and for their cultural reactions. In the tables of the Appendix the complete reactions are shown.

THE ACID-FORMING GROUP OF BACTERIA.

The acid-forming group of bacteria have been grouped arbitrarily as shown in figure 22. One hundred and thirty-two cultures were examined and were divided into four classes. The first class comprised 89.39 per cent of the cultures. The reactions of this class are shown in figure 22. All the organisms were cocci which produced no liquefaction of gelatin. The Gram stain was either positive or negative, nitrate was not reduced, and some formed pigment while others did not. Dextrose, galactose, and lactose were fermented. Some cultures fermented saccharose. Of those that fermented saccharose, the ability to ferment raffinose, starch, inulin, mannite, glycerin, and salicin varied as may be seen. The same may be said regarding those cultures which did not ferment saccharose. The second class was made up of nonliquefying bacilli, Gram positive, nitrate reduction positive or negative, and all produced pigment. Dextrose, galactose, lactose, and saccharose were fermented; raffinose positive or negative, starch positive or negative, inulin not fermented, mannite positive or negative, glycerin not fermented, and salicin positive or negative. This class comprised 3.03 per cent of the acid group cultures. The third

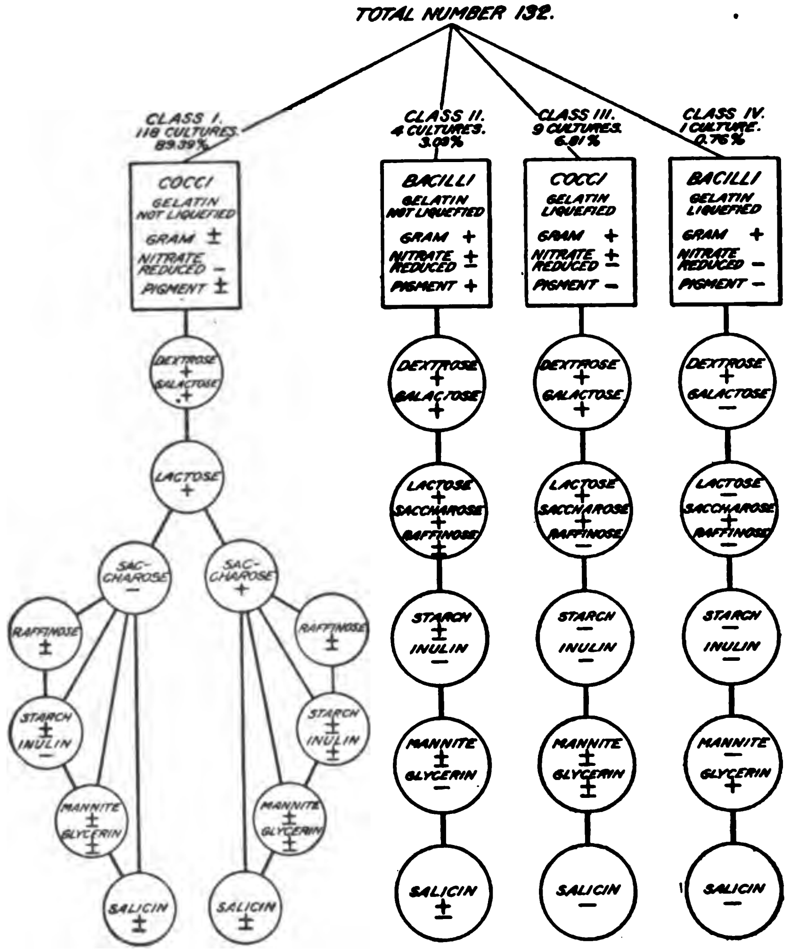
TOTAL NUMBER 132.
CLASS I. 118 CULTURES. 89.39%
COCCI GELATIN NOT LIQUEFIED GRAM ± NITRATE REDUCED − PIGMENT ±
DEXTROSE + GALACTOSE +
LACTOSE +
SAC-CHAROSE −
SAC-CHAROSE +
RAFFINOSE ±
RAFFINOSE ±
STARCH ± INULIN −
STARCH ± INULIN ±
MANNITE ± GLYCERIN ±
MANNITE ± GLYCERIN ±
SALICIN ±
SALICIN ±
CLASS II. 4 CULTURES. 3.03%
BACILLI GELATIN NOT LIQUEFIED GRAM + NITRATE REDUCED ± PIGMENT +
DEXTROSE + GALACTOSE +
LACTOSE + SACCHAROSE + RAFFINOSE ±
STARCH ± INULIN −
MANNITE ± GLYCERIN −
SALICIN ±
CLASS III. 9 CULTURES. 6.81%
COCCI GELATIN LIQUEFIED GRAM + NITRATE REDUCED ± PIGMENT −
DEXTROSE + GALACTOSE +
LACTOSE + SACCHAROSE + RAFFINOSE −
STARCH − INULIN −
MANNITE ± GLYCERIN ±
SALICIN −
CLASS IV. 1 CULTURE. 0.76%
BACILLI GELATIN LIQUEFIED GRAM + NITRATE REDUCED − PIGMENT −
DEXTROSE + GALACTOSE −
LACTOSE − SACCHAROSE + RAFFINOSE −
STARCH − INULIN −
MANNITE − GLYCERIN +
SALICIN −

FIG. 22.—The acid-forming group of bacteria.

class contained 6.81 per cent of the cultures and was made up of liquefying cocci, Gram positive, nitrate reduction positive or negative, and none produced pigment. The acid production was as follows: Dextrose, galactose, lactose, and saccharose positive; raffinose, inulin, and starch negative; mannite and glycerin positive or negative; and salicin negative.

One culture formed the fourth class. It was a liquefying Gram positive bacillus which reduced nitrates and formed no pigment.

Acid was formed in dextrose, lactose, saccharose, and glycerin. The complete reactions of each variety of bacteria are shown in Table I of the Appendix.

In general it may be said that the majority of the acid group which survived pasteurization at 62.8° C. (145° F.) were nonliquefying cocci which varied widely in their ability to ferment the various sugars. A small percentage of acid-forming bacilli also survived, together with a few acid-liquefying bacteria.

THE INERT GROUP OF BACTERIA.

The study of the inert group has not been given much attention. All bacteria which produced no change in litmus milk after 14 days' incubation at 30° C. (86° F.) were classed according to the milk-tube method as inert organisms. The group would therefore contain not only those bacteria which did not produce any change in milk under any condition, but also any organisms which did not happen to grow in the milk tubes and those which might produce a change in milk after the 14 days' incubation period.

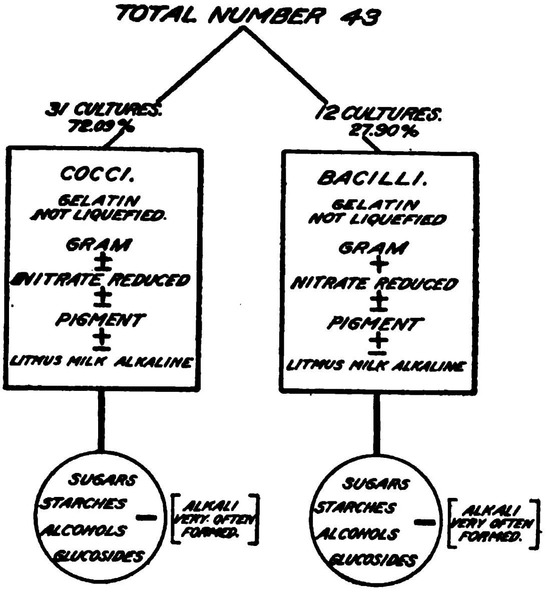

FIG. 23.—The alkali-forming group of bacteria.

In a number of samples agar streak cultures were made from the litmus milk tubes which showed no change. Sometimes none of the agar cultures showed growth; in other cases approximately 2 per cent, 5 per cent, 25 per cent, 80 per cent, and occasionally 100 per cent showed growth on agar streaks. When those agar cultures were reinoculated into litmus milk, some would not produce any reaction and others a slight alkaline reaction after long incubation. Often a yellow color was noticed in the litmus milk culture which indicated an inert yellow pigment-forming organism.

THE ALKALI-FORMING GROUP OF BACTERIA.

The alkali-forming bacteria constitute a group which has been given but little study in connection with the bacterial flora of milk. In the differentiation of the various groups on litmus lactose gelatin plates, organisms of this group would be entirely missed, but they are easily found by the milk-tube method. Forty-three of these organisms isolated from pasteurized milk have been studied and grouped arbitrarily, as shown in figure 23. The alkali group was made up of 72.09 per cent of cocci and 27.90 per cent of bacilli.

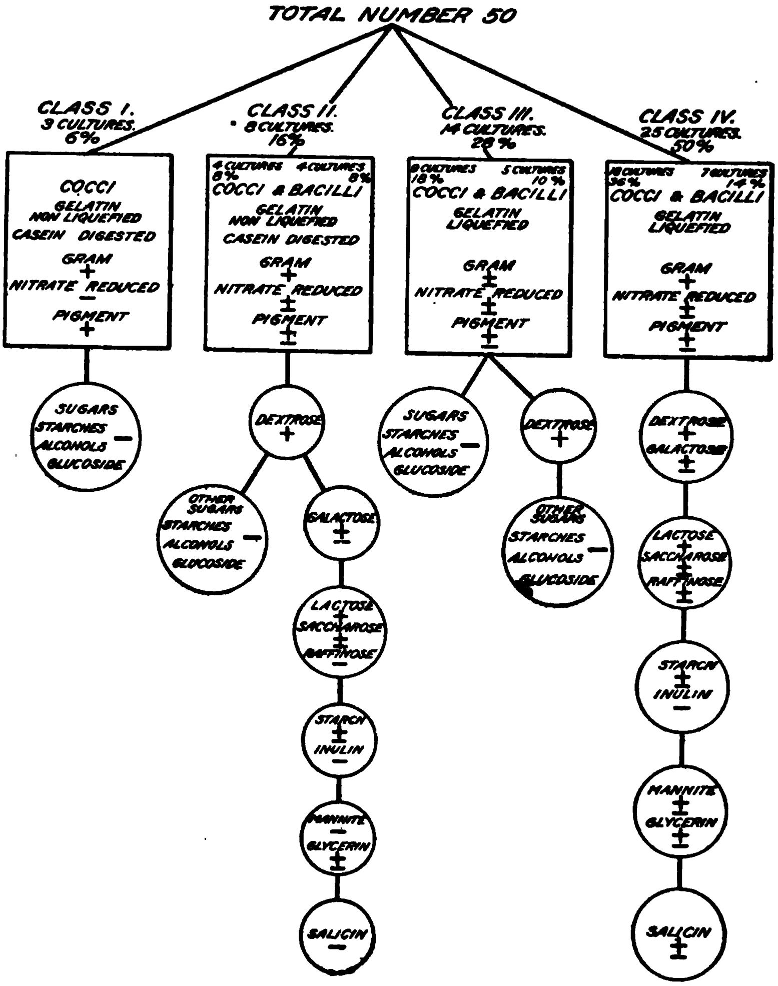

FIG. 24.—The peptonizing group of bacteria.

It is not necessary to go into minute details regarding these organisms, for their characteristics are plainly shown in the figure. They did not liquefy gelatin, and produced a strong alkaline reaction in litmus milk. No acid was produced in the sugars, starches, alcohols, or in the glucosid used in the investigation, but an alkaline reaction was often found. In litmus milk often enough alkali was produced to dissolve the casein. That will always happen if the period of incubation is long enough. The complete characteristics are shown in the Appendix in Table II. A more extended study of the alkali group is under way in the research laboratories of this division.

THE PEPTONIZING GROUP OF BACTERIA.

The peptonizing bacteria include only those which peptonize the casein of milk. Fifty of this type of organisms were studied, and their characteristics are shown fully in the Appendix in Table III. They were divided arbitrarily into four classes, as shown in figure 24. It may be seen that the bacteria of classes 1 and 2 did not liquefy gelatin during 30 days' incubation, but did peptonize casein. The peptonization of casein was determined by streak cultures on casein agar slopes by the following method:

After 14 days' incubation the slopes were flowed with N/10th lactic acid. If no peptonization has taken place the casein will be precipitated by the acid. If peptonization has gone on, then the casein agar will remain clear, showing that the casein has been dissolved. The use of casein agar for the determination of peptonizing bacteria in milk is fully described in another publication[1] of this department. It will be seen from figure 24 that classes 1 and 2 comprise both cocci and bacilli, some of which did not ferment sugars, while others produced acid. Classes 3 and 4 is made up of bacteria which liquefy gelatin and may or may not ferment the sugars. It is interesting to note that out of 225 cultures of bacteria studied only 3, or 1.35 per cent, formed spores. Those 3 cultures were found among the 50 peptonizing organisms making only 6 per cent of the peptonizing spore-forming organisms.

THE GAS-FORMING BACTERIA.

During the study of 225 cultures selected at random from the samples of pasteurized milk only two organisms were found which produced gas in milk. One of the gas-forming bacteria, culture 417, was a Gram negative short bacillus which peptonized casein but did not liquefy gelatin. It produced gas in lactose broth and acid in dextrose, saccharose, raffinose, starch, and salicin broths. No acid was formed in lactose, galactose, mannite, glycerin, or inulin broths. Nitrate solution was reduced. Gas was produced in litmus milk and the milk was curdled with some peptonization. It is evident that this bacillus did not belong to the colon-aerogenes group.

The other organism is an entirely new type so far as known. This culture known as Z produced gas in milk but not in lactose broth.

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[1] Ayers, S. Henry. Casein media adapted to determining bacteria in milk. United States Department of Agriculture, Bureau of Animal Industry, Twenty-eighth Annual Report, 1911 (in press).

Culture Z was a long motile Gram negative bacillus. In a hanging drop preparation a few cells had an enlargement at one end which probably represented spores, although it was impossible to demonstrate their presence by staining reactions. Their survival of an exposure to a temperature of 93.3° C. (200° F.) for 30 minutes seemed to affirm the presence of spores. It grew slowly on agar streaks and produced a slimy growth. A 2 days' old culture often showed extremely long types of organisms. Acid was produced in dextrose, galactose, and salicin broths, but not in saccharose, mannite, glycerin, raffinose, inulin, or starch broths. When these broths were used for gas production it was found in one experiment that culture Z produced gas in raffinose, mannite, and starch broths after 14 days' incubation at 30° C. (86° F.), but none in any of the other broths. This experiment was repeated and no gas was found in any of the broths. Nitrate solution was reduced and gelatin was not liquefied after 30 days' incubation at 18° C. (64.4° F.). This culture produced acid and gas in milk and coagulated it after 14 days. The ability to produce gas in milk through a long period is one of the striking characteristics of this organism. In order to determine how long culture Z would continue to produce gas in milk, a 25 cubic centimeter burette was inverted and inserted through a rubber cork into an Erlenmeyer flask containing 200 cubic centimeters of milk, as shown in figure 25. By opening the stopcock of the burette the milk could be drawn to the top and the tube filled. After sterilizing, the milk was inoculated with culture Z and incubated at 30° C. (86° F.). The gas produced was recorded daily and when the burette was filled with gas the stopcock was opened and the tube was again filled with milk. In that way it was possible to record gas production from milk over an indefinite period. As may be seen from figure 26, this organism was able to produce gas through a period of 46 days. The fermentation began after 24 hours' incubation when from 3 to 4 cubic centimeters of gas was formed daily until the fourteenth day, when the milk was curdled. At that time the daily gas production increased and was sometimes as high as 15 cubic centimeters. The increased gas production continued until the thirty-first day when it was reduced to approximately 4 cubic centimeters per day. The gas produced was hydrogen and carbon dioxide. The ability of culture

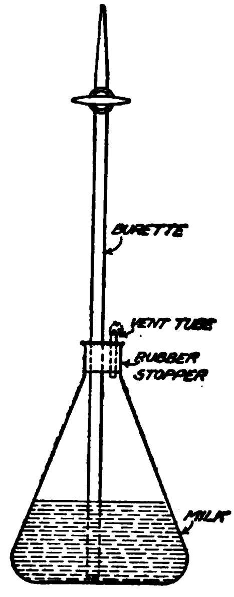

FIG. 25.—Apparatus for the determination of gas production in milk.

Z to produce gas in milk continuously for a long period, together with the fact that while gas was formed in milk lactose in broth was not fermented, differentiates this organism from the ordinary types of gas formers. A more extended study of this type of organism is under way in the research laboratories of this division.

The survival of pasteurization by gas-forming bacteria is of considerable importance, since it has been suggested to make the presence of the colon group an indication of recontamination of pasteurized milk or of inefficient pasteurization. Several boards of health are at present using such a test. If gas-forming organisms do not survive pasteurization, then of course their presence in pasteurized milk means recontamination or inefficient pasteurization. If, however, certain types of gas-forming bacteria do survive the process, then the test is of no value. In order to determine if gas-forming bacteria survived pasteurization for 30 minutes at 62.8° C. (145° F.), 19 samples of raw milk were heated in sterile flasks. Fermentation

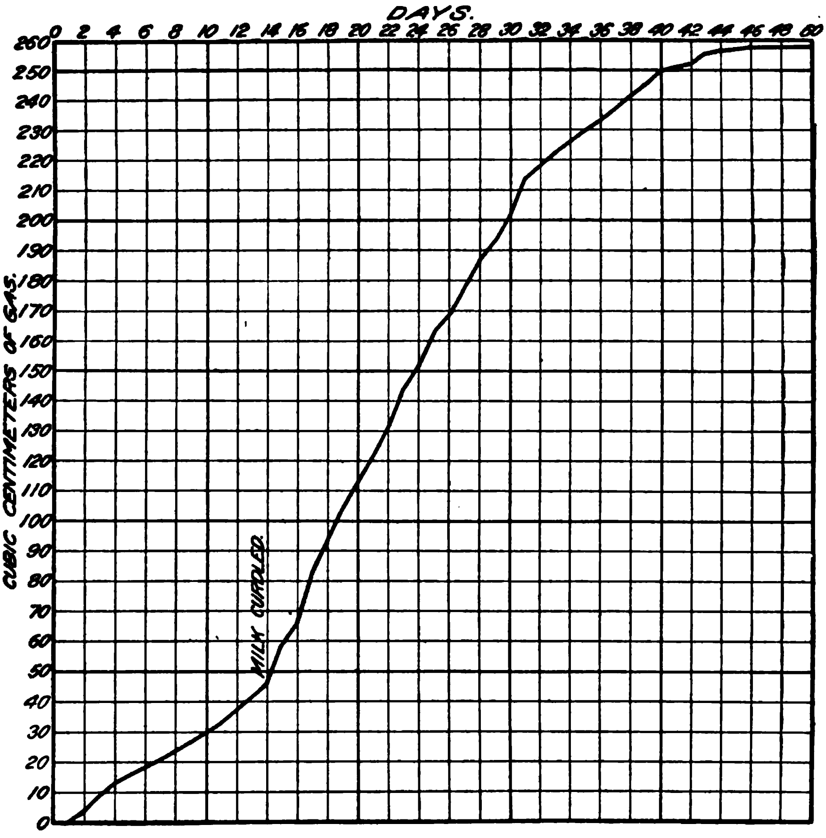

FIG. 26.—Gas produced by culture Z.

tubes in sets of four were then inoculated with 1 cubic centimeter and 5 cubic centimeters of both the raw and the pasteurized milk. The results are shown in Table 18. Twelve of the samples of raw milk showed the presence of gas-forming organisms in lactose bile tubes when 1 cubic centimeter of milk was used for inoculation. After pasteurization three samples showed gas when 1 cubic centimeter was used and eight samples when 5 cubic centimeters of milk was used. When dextrose liver broth fermentation tubes were used, a larger number of samples of the pasteurized milk showed the presence of gas-forming bacteria. It may be seen from the table that the number of gas producers in the raw and pasteurized milk was low as determined by the dilution and the number of tubes of each set of four which showed gas. For example, sample 1, four tubes of lactose bile, each inoculated with 1 cubic centimeter of raw milk, showed no gas, which means that no gas-forming organisms were present in 4 cubic centimeters of the raw milk. Four tubes, each inoculated with 5 cubic centimeters of the same milk pasteurized, showed gas in two tubes. That means at least one gas-forming organism in every 10 cubic centimeters of the milk.

TABLE 18.—*Gas production in lactose-bile and dextrose-liver broths inoculated with raw milk and milk pasteurized at 62.8° C. (145° F.) for 30 minutes. Four tubes used in each dilution.*

Sample number.	Gas produced in—					
	Lactose-bile broth.			Dextrose-liver broth.		
	Inoculated with 1 c. c. raw milk.	Inoculated with 1 c. c. pasteurized milk.	Inoculated with 5 c. c. pasteurized milk.	Inoculated with 5 c. c. raw milk.	Inoculated with 1 c. c. pasteurized milk.	Inoculated with 5 c. c. pasteurized milk.
	Tubes.	*Tubes.*	*Tubes.*	*Tubes.*	*Tubes.*	*Tubes.*
1	0	0	2	0	3	2
2	0	0	0	0	3	2
3	0	0	0	0	1	0
4	3	0	1	1	0	1
5	0	0	0	3	0	2
6	3	0	3	3	0	2
7	3	0	1	3	0	1
8	0	0	0	0	0	2
9	2	0	0	0	0	2
10	2	0	0	0	0	0
11	1	0	0	0	3	2
[1] 12	....	0	0	....	0	0
13	4	0	0	3	1	4
14	3	0	0	4	0	0
15	1	3	1	2	1	1
16	4	2	4	4	2	2
17	4	0	0	4	0	2
18	....	....	4	....	....	....
19	3	1	4	....	....	....

[1] Milk incubated at 37° C. for 18 hours and then pasteurized.

Litmus lactose agar plates were made and inoculated from almost every sample which showed gas in the bile tubes, but no organisms of the colon type were found. The only gas producer which was found was a spore-forming anaerobic bacillus of the butyric group. One of these organisms, known as culture T, produced acid in dextrose, galactose, saccharose, raffinose, and starch broths, and gas in dextrose, galactose, lactose, saccharose, and starch broths. In this work no organisms of the colon group were found to survive pasteurization, but gas was often produced in lactose bile tubes inoculated with pasteurized milk. The gas production, however, was not due to organisms of the colon group, but to those of the butyric-acid group. This anaerobic butyric bacillus produced gas in lactose bile tubes and would appear in the preliminary tests for the colon bacillus. Therefore, if only lactose bile fermentations were used to determine the presence of the colon group in pasteurized milk, the anaerobic butyric types of bacteria would produce fermentations which would be taken as an indication of the colon group. It is evident, then, that the presence of the colon group of organisms in milk must be determined by something more than simply lactose bile fermentation tubes. These results are by no means conclusive, for if a larger number of samples had been examined colon bacilli might have been found which survived pasteurization. De Jong and De Graaff,[1] working on various strains of *Bacillus coli*, found some forms which required 30 minutes heating at 70°-72° C. (158°-161.6° F.) to destroy. Zelenski[2] also found some strains of *B. coli* which resisted high temperatures. Evidently resistant types of the colon group do exist and that fact complicates the value of the colon test for reinfection of pasteurized milk.

THERMAL DEATH POINTS OF BACTERIA WHICH SURVIVE PASTEURIZATION.

As a matter of purely scientific interest the thermal death points of several bacteria which survived pasteurization were determined. The determinations were made by heating 2 days' old lactose dibasic broth cultures for 30 minutes in Sternberg bulbs. After heating, the contents of the bulbs were inoculated into litmus milk tubes. Cultures were selected from the acid, alkali, and peptonizing groups for the experiment. The results are shown in Table 19. Culture 40 of the acid group stood as high as 79.4° C. (175° F.). Numbers 58 and 156 were destroyed at 73.9° C. (165° F.) and culture 81 at 65.6° C. (150° F.). One culture of the alkali group was destroyed at 65.6° C. (150° F.). Culture 450 of the peptonizing group was destroyed at 71.1° C. (160° F.), while the thermal death point of culture 456 was indefinite, although about 79.4° C. (175° F.).

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[1] De Jong, D. A., and De Graaff, W. C. Die Coli-Kontrolle der pasteurisierten Milch. [Nederlandsch Weekblad voor Zuivelbereiding en Veeteelt, vol. 12, Nos. 37 and 38, 1906]. Abstract: Milchwirtschaftliches Zentralblatt, vol. 3, No. 6, pp. 265-268. Leipzig, June, 1907.

[2] Zelenski, Thaddeus. Zur Frage der Pasteurisation der Säuglingsmilch. Jahrbuch für Kinderheilkunde, vol. 63, pp. 288-307. Berlin, 1906. Abstract: Centralblatt für Bakteriologie, Parasitenkunde und. Infektionskrankheiten. Abteilung 2, vol. 18, No. 4-6, p. 175. Jena, Mar. 14, 1907.

TABLE 19.—*Thermal death point of bacteria surviving pasteurization.*

Culture.	30 minutes in Sternberg bulbs at—								
	57.2° C. (135° F.).	60° C. (140° F.).	62.8° C. (145° F.).	65.6° C. (150° F.).	68.3° C. (155° F.).	71.1° C. (160° F.).	73.9° C. (165° F.).	76.7° C. (170° F.).	79.4° C. (175° F.).
ACID GROUP.									
Culture 58	....	....	++	++	++	++	−−	−−	−−
Culture 40	....	....	++	++	++	++	++	++	+−
Culture 81	....	....	++	−−	−−	−−	−−	−−	−−
Culture 156	....	....	++	++	++	++	−−	−−	−−
ALKALI GROUP.									
Culture 311	++	++	++	−−	−−	−−	−−		
PEPTONIZING GROUP.									
Culture 450	++	++	++	++	+−	−−	−−		
Culture 456	++	++	++	++	+−	++	+−	+−	

In one sample of milk heated at 82.2° C. (180° F.) for 30 minutes it was found by the tube method of group differentiation that a very large percentage of the acid group survived. Sixty-four milk cultures of the resistant acid bacteria were examined roughly for their thermal death point by inoculating fresh litmus milk tubes with one drop of the milk culture. One set of milk tubes was then heated for 30 minutes at 87.8° C. (190° F.) in a water bath and another set at 93.3° C. (200° F.) for the same length of time. Of the 64 tubes heated at 87.8 C. (190° F.) 27 showed growth, but all were destroyed at 93.3° C. (200° F.). These heat-resistant acid-forming organisms are of great importance in connection with the pasteurization of milk. From a purely scientific standpoint they are of interest, since in general the thermal death point of vegetative cells has been believed to be below 60° C. (140° F.). From the numbers of these heat-resistant organisms it is evident that they are not uncommon in milk.

THE POSSIBLE USE IN PASTEURIZATION OF ACID-FORMING BACTERIA OF HIGH THERMAL DEATH POINT.

Since certain strains of typical lactic-acid bacteria are known to be able to withstand pasteurizing temperatures, it seems possible to make use of their resistance. It has been suggested that cultures of lactic-acid bacteria be added to milk after pasteurization in order to insure a normal souring. A process of that nature would necessarily involve a danger of contamination by pathogenic bacteria from employees at the dairy, since the acid-forming bacteria are to be added after the heating process. By the use of a lactic-acid organism of high thermal death point it would be possible to add the culture to the raw milk and then pasteurize. One experiment was tried to show this point. As may be seen from Table 20, a sample of certified milk was divided into two parts of 800 cubic centimeters each. Both portions were heated in sterile flasks for 30 minutes at 62.8° C. (145° F.). To one flask 5 cubic centimeters of a high-temperature resistant lactic-acid culture was added before pasteurization. The effect of the addition of the culture can be seen by the change in the milk when held at room temperature. After four days the milk without the culture was curdled with a rennet curd and was partly peptonized, very little acid having developed. The other sample to which the heat resistant culture was added was curdled on the fourth day and showed a smooth firm acid curd with no digestion. By the addition of the culture before pasteurization in sealed bottles subsequent infection would be impossible. This possibility of addition of high temperature resistant lactic-acid bacteria is merely suggested for those who advocate the addition of cultures after pasteurization.

TABLE 20.—*Change in acid development in pasteurized milk produced by the addition of high-temperature resisting lactic-acid bacteria previous to pasteurization.*

PER CENT LACTIC ACID.

[Samples held at room temperature, 21.1°-23.9° C. (70°-75° F.).]

	Lactic acid after—				
	0 day.	1 day.	2 days.	3 days.	4 days.
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Certified milk pasteurized at (145°) 62.8° C. for 30 minutes	0.17	0.17	0.16	......	[1]0.31
Some of same milk with 5 c. c. of high-temperature resisting lactic-acid culture added to 800 c. c. of milk; milk then pasteurized at 62.8° C. (145° F.) for 30 minutes	.17	.17	.18	......	[2].50

[1] Curdled and peptonized.

[2] Curdled, acid curd.

QUALITATIVE STUDY OF THE COMPLETE BACTERIAL FLORA OF ONE SAMPLE OF PASTEURIZED MILK.

Since in the qualitative study of the bacteria surviving pasteurization a few typical cultures representing each group were selected from each sample, it was thought advisable to make a more thorough qualitative study of the bacteria in one sample of pasteurized milk.

The complete bacterial flora of one sample of milk pasteurized for 30 minutes at 60° C. (140° F.) and another portion of the same milk pasteurized at 65.6° C. (150° F.) were studied qualitatively.

Litmus lactose gelatin plates were made, and after 6 days' incubation at 18° C. (64.4° F.) each colony was picked off, purified by plating, and studied. The A series of cultures is made up of 176 cultures picked from a plate from milk pasteurized at 60° C. (140° F.). The B series is composed of 92 cultures from a plate from milk pasteurized at 65.6° (150° F.). Each series has been divided into five

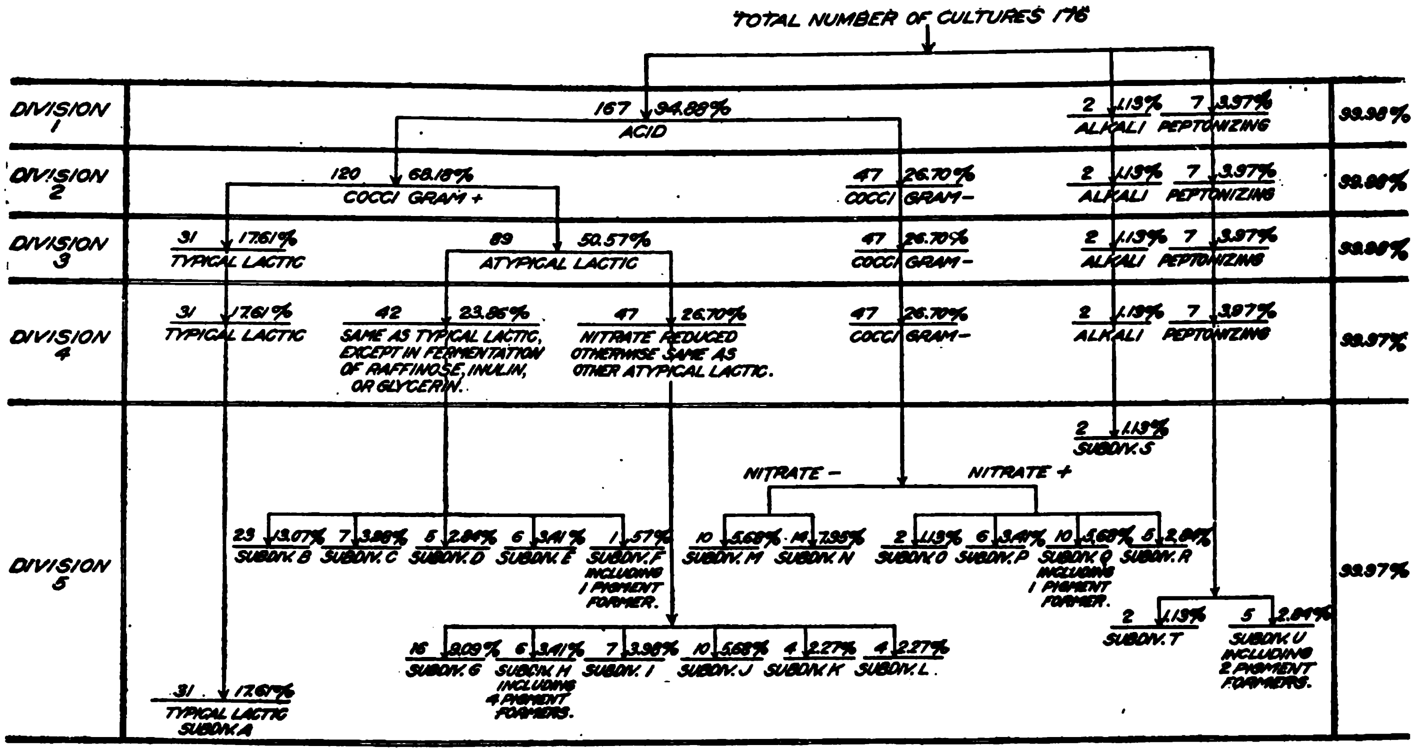

FIG. 27.—A series. Cultures from milk pasteurized at 60° C. (140° F.) for 30 minutes.

divisions according to the differentiation of the bacteria. Table 21 shows the A series. Division 1, figure 27, shows the division of the 176 cultures of bacteria which survive pasteurization at 60° C. (140° F.) into three groups—the acid, the alkali, and the peptonizing group.

	Per cent.
Acid group	94. 88
Alkali group	1. 13
Peptonizing group	3. 97

In division 2 the acid group has been further divided as shown and the percentages given. Each division shows the complete percentages of the various classes. Division 5 shows the final classification and percentages. Each subdivision of division 5 has been given a letter which makes it possible by the use of the following key to determine the complete reactions of the bacteria in each subdivision:

KEY TO LETTERS AND SIGNS USED IN FORMULA SHOWING CULTURAL REACTIONS OF THE SUBDIVISIONS.

The formula reads in the order of the numerals:

1. B—Bacilli.
   C—Cocci.
2. A—Gelatin not liquefied.
   X—Gelatin liquefied.
      X_1-1–10 mm. of liquefaction.
      X_2-over 10 mm. of liquefaction.
3. Gram..........(±)
4. Nitrate reduced..........N (±)
5. Dextrose (sugar broth)..........D (±)
6. Lactose (sugar broth)..........L (±)
7. Saccharose (sugar broth)..........C (±)
8. Galactose (sugar broth)..........G (±)
9. Mannite..........M (±)
10. Raffinose (sugar broth)..........R (±)
11. Glycerin broth..........Glyc. (±)
12. Inulin broth..........I (±)
13. Starch broth..........S (±)
14. Pigment production..........P (±)

The formulas of the reactions of the subdivisions are given in Table 21.

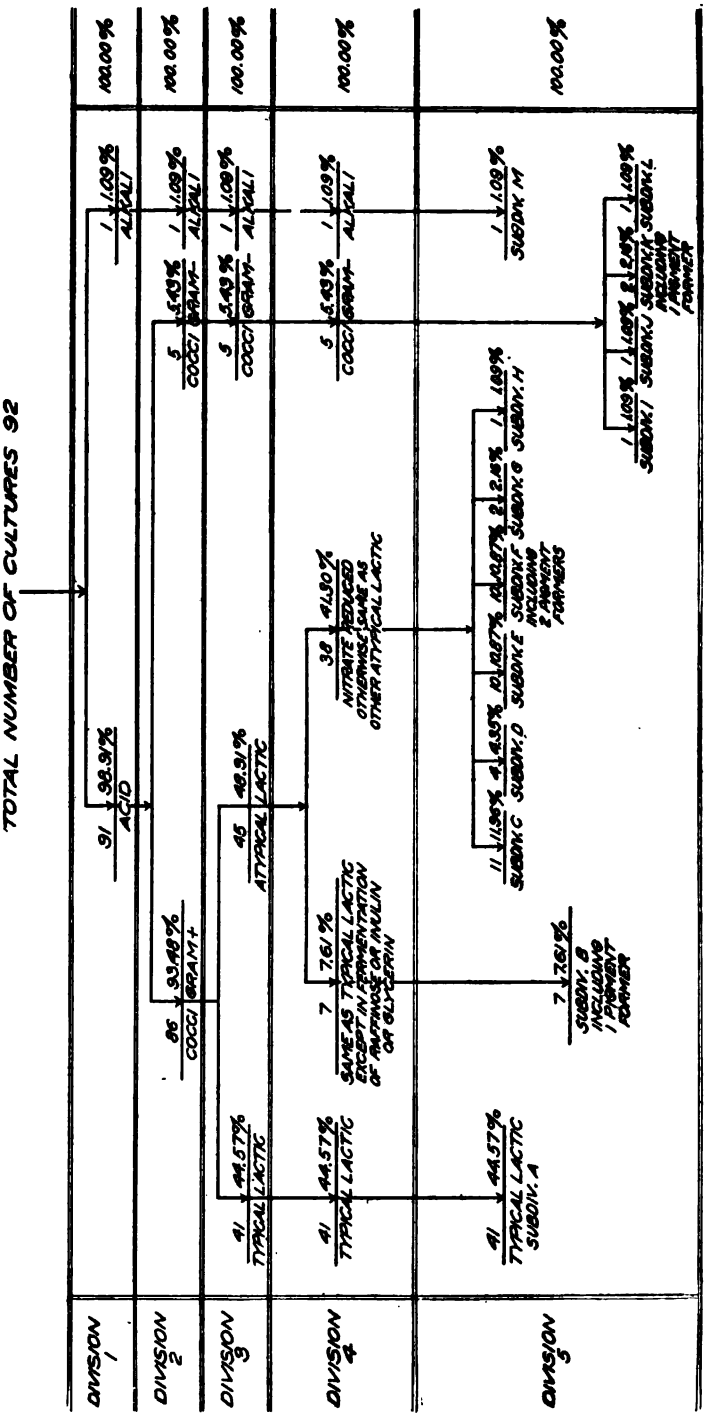
TOTAL NUMBER OF CULTURES 92
DIVISION 1
DIVISION 2
DIVISION 3
DIVISION 4
DIVISION 5
91 98.91% ACID
1 1.09% ALKALI
86 93.48% COCCI GRAM+
5 5.43% COCCI GRAM-
41 44.57% TYPICAL LACTIC
45 48.91% ATYPICAL LACTIC
7 7.61% SAME AS TYPICAL LACTIC EXCEPT IN FERMENTATION OF RAFFINOSE OR INULIN OR GLYCERIN
38 41.30% NITRATE REDUCED OTHERWISE SAME AS OTHER ATYPICAL LACTIC
41 44.57% TYPICAL LACTIC SUBDIV. A
7 7.61% SUBDIV. B INCLUDING 1 PIGMENT FORMER
11 11.96% SUBDIV. C
4 4.35% SUBDIV. D
10 10.87% SUBDIV. E
10 10.87% SUBDIV. F INCLUDING 2 PIGMENT FORMERS
2 2.17% SUBDIV. G
1 1.09% SUBDIV. H
1 1.09% SUBDIV. I
1 1.09% SUBDIV. J
2 2.17% SUBDIV. K INCLUDING 1 PIGMENT FORMER
1 1.09% SUBDIV. L
1 1.09% SUBDIV. M
100.00%

FIG. 28.—B series. Cultures from milk pasteurized at 65.6° C. (150° F.) for 30 minutes.

TABLE 21.—*Cultural reactions of organisms in subdivisions—cultures of A series from milk pasteurized for 30 minutes at 60° C. (140° F.).*

Subdivision.	Formula of reactions.
A	CA+N−D+L+C±G+M±R−Glyc.−I−S±.
B	CA+N−D+L+C±G+M±R+Glyc.−I−S+.
C	CA+N−D+L+C±G+M±R+Glyc.−I−S−.
D	CA+N−D+L+C±G+M±R−Glyc.+I−S+.
E	CA+N−D+L+C±G+M±R−Glyc.+I−S−.
F	CA+N−D+L+C±G+M±R−Glyc.−I−S−P+.
G	CA+N+D+L+C±G+M±R+Glyc.−I−S+.
H	CA+N+D+L+C±G+M±R−Glyc.−I−S−.
I	CA+N+D+L+C±G+M±R+Glyc.−I−S+.
J	CA+N+D+L+C±G+M±R+Glyc.+I−S+.
K	CA+N+D+L+C±G+M±R+Glyc.−I−S−.
L	CA+N+D+L+C±G+M±(other reactions (±)).
M	CA−N−D+L+C±G+M±R−Glyc.−I−S±.
N	CA−N−D+L+C±G+M±(other reactions (±)).
O	CA−N+D+L−C±G+M±R+Glyc.+I+S+.
P	CA−N+D+L+C±G+M±R+Glyc.+I−S+.
Q	CA−N+D+L+C±G+M±R+Glyc.−I−S±.
R	CA−N+D+L+C±G+M±R−Glyc.+I−S±.
S	CA+N+D−L−C−G−M−R−Glyc.−I−S−P+(red).
T	CX_2−N−D+L+C+G+M−R−Glyc.−I−S−.
U	CX_2+N−D+L+C+G+M±R−Glyc.±I−S−P±.

The formula reads as follows, as shown in table:

Subdivision A:

C. Coccus.
A. Gelatin not liquefied.
+. Gram+.
N−. Nitrate not reduced.
D+. Acid produced in dextrose broth.
L+. Acid produced in lactose broth.
C±. May or may not produce acid in saccharose broth.
G+. Acid produced in galactose broth.
M±. May or may not produce acid in mannite broth.
R−. No acid produced in raffinose broth.
Gly.−. No acid produced in glycerin broth.
I−. No acid produced in inulin broth.
S±. May or may not produce acid in starch broth.

The B series of cultures from milk pasteurized at 65.6° C. (150° F.) were divided in a similar manner as shown in Fig. 28. The formulas of the reactions of the subdivisions are given in Table 22.

TABLE 22.—*Cultural reactions of organisms in subdivisions—cultures of B series from milk pasteurized for 30 minutes at 65.6° C. (150° F.).*

Subdivision.	Formula of reactions.
A	CA+N−D+L+C±G+M±R−Glyc.−I−S±.
B	CA+N−D+L+C±G+M±R+Glyc.−I−S±.
C	CA+N+D+L+C±G+M±R+Glyc.−I−S+.
D	CA+N+D+L+C±G+M±R+Glyc.−I−S−.
E	CA+N+D+L+C±G+M±R−Glyc.−I−S+.
F	CA+N+D+L+C±G+M±R−Glyc.−I−S−.
G	CA+N+D+L+C±G+M±R+Glyc.+I−S+.
H	CA+N+D+L+C±G+M±R+Glyc.−I+S+.
I	CA−N−D+L+C±G+M±R−Glyc.−I−S+.
J	CA−N−D+L+C±G+M±R+Glyc.−I+S+.
K	CA−N+D+L+C±G+M±R+Glyc.−I−S+.
L	CA−N+D+L+C±G+M−R−Glyc.−I−S+.
M	CA−N−D−L−C−G−M−R−Glyc.−I−S−.

By this system of division one is able to see at a glance the general groups of bacteria which survived pasteurization in one sample of milk heated at 60° C. (140° F.) and 65.6° C. (150° F.). Or if desired, the complete reactions of the various classes of bacteria can be determined. There is little that need be said regarding the results, for they are plainly shown. The most noticeable features were the high percentage of the acid-forming bacteria and the low percentage of the peptonizing group. It may be seen that a large percentage of the acid group were typical lactic acid bacteria as based on the formula of subdivision A.

SUMMARY.

1. The average temperature used throughout the country with the "holder" process is 62.8° C. (145° F.). With the "flash" process, 71.1° C. (160° F.).

Reports from 219 milk plants show that 75 used the "holder" and 144 the "flash" process. The range in temperatures is from 60° C. (140° F.) to 82.2° C. (180° F.). Of the plants using the "holder" process only 1.3 per cent employ temperatures too low for proper pasteurization. Of those which use the "flash" process approximately 42 per cent use temperatures too low to be effective.

2. Percentage bacterial reduction is of no value in determining the efficiency of the process of pasteurization. As a general rule when the bacterial content of raw milk is high there will be a high percentage reduction. When the bacterial content is low, then the percentage reduction is often low. The percentage bacterial reduction may be 99.9 per cent and yet the pasteurized milk may show a count of 100,000 per cubic centimeter. When the pasteurized milk contains only 10,000 bacteria per cubic centimeter the percentage reduction may only have been 95 per cent. It is often impossible to obtain a 99 per cent reduction when a good quality of milk is pasteurized, therefore regulations which require a 99 per cent reduction of bacteria during pasteurization are of no value.

3. A heating period of three hours causes a marked increase in the reduction of bacteria in milk over one-half hour's heating, when a temperature of 54.4° C. (130° F.) and 57.2° C. (135° F.) are used. At 60° C. (140° F.) the increased reduction is much less. According to the results of one experiment in this investigation, a six hours' period of heating at 62.8° C. (145° F.) does not produce any more destruction of bacteria than does one-half hour's heating.

4. Sudden cooling from 62.8° C. (145° F.) or 71.1° C. (160° F.) within 15 seconds to from 1.7°–3.9° C. (35°–39° F.) does not cause any destruction of bacteria. The long-prevailing idea that sudden cooling is an essential part of the process of pasteurization is erroneous so far as any increased destruction of bacteria is concerned. Its

value lies only in the fact that milk suddenly cooled is not allowed to stand at temperatures between 37.8° C. (100° F.) and 10° C. (50° F.), where rapid bacterial development might occur.

5. Four distinct groups of bacteria, the acid-forming, the inert, the alkali-forming, and the peptonizing, survive pasteurization, as differentiated by their reactions in litmus milk after 14 days' incubation at 30° C. (86° F.).

The percentage of the acid group is increased by pasteurization while the other groups are decreased in their percentage of the total bacteria. The average percentage of lactic acid bacteria in raw milk which survive pasteurization for 30 minutes at 62.8° C. (145° F.) ranges from 1.27 per cent to 4.55 per cent in the various grades of milk.

When the temperature of pasteurization is below 76.7° C. (170° F.) the bacterial flora of milk is composed for the most part of organisms of the acid group. At temperatures above 76.7° C. (170° F.) the acid group is largely destroyed and the majority of the bacteria which survive are of the peptonizing type. These bacterial group relations are clearly shown in the figures in the conclusions.

6. When different grades of milk are pasteurized at 62.8° C. (145° F.) in the laboratory and held at room temperature the bacterial flora may undergo three distinct changes. First, when a fair quality of milk is pasteurized the acid group may develop at once and overgrow all the other groups, forming acid and producing a normal curd. Second, when a poor quality of milk is pasteurized the peptonizing group may grow rapidly at first along with the acid group, which later overgrows them. In this case the milk will first become curdled with a rennet curd due to the peptonizing bacteria, then later will become sour from the development of the lactic-acid group of organisms. Third, when a good grade of milk is pasteurized the peptonizing bacteria may overgrow the acid group of organisms so that the milk becomes peptonized without the development of any acid. These same grades of milk, treated in the same manner but held in an ice chest at 10° C. (50° F.), show entirely different changes in their bacterial contents. The growth of the peptonizing group is restrained so that they are of little importance. The percentage of the acid group remains about the same through a long period. Occasionally the percentage of the alkali group may increase after five days, but eventually the acid group forms the major group. These results were obtained from laboratory experiments and only indicate possible changes in the bacterial flora of pasteurized milk when held at different temperatures. They show the delicate balance between the bacterial groups, but can not be applied to indicate the bacterial changes in milk pasteurized and handled under commercial conditions.

7. A qualitative study of the acid group shows that many organisms giving characteristics of the typical lactic-acid bacteria survive pasteurization for 30 minutes at 62.8° C. (145° F.). Other lactic-acid forming bacteria survive which may form pigment or vary from the typical lactic types in the fermentative reactions.

The inert group was made up of organisms which produce no change in litmus milk during 14 days' incubation, and therefore include many which did not grow, but which according to the method of differentiation would be included as inert forms. The only truly inert form recognized was a yellow pigment-forming organism. The inert group is probably of little importance.

The alkali group which survive pasteurization is of importance. Bacteria of this group can not be differentiated from those of the inert group or from slow acid-forming organisms by plating, but are easily determined by the milk-tube method. They grow at low temperatures and produce a strong alkaline reaction in milk. In pure cultures enough alkali is produced to dissolve the casein. No acid is produced in fermentation broths, but often an alkaline reaction is found.

The peptonizing group includes those organisms which peptonize casein. A number of the organisms isolated peptonized casein, but did not liquefy gelatin. Various types of this group are able to survive pasteurization and vary widely in their cultural characteristics.

The few gas-forming bacteria in pasteurized milk, so far as the results of this investigation indicate, do not include organisms of the colon-aerogenes group. One gas-forming organism was found which produced gas in milk and peptonized casein. Another culture, known as Z, seems to be an entirely new type, which is characterized by its ability to produce gas continuously in milk through a long period, and by the fact that while gas is formed in milk none is formed in lactose broth.

Gas-forming anaerobic bacteria are often found in milk which produce gas in lactose bile tubes and which might be mistaken in a preliminary test for the colon organism.

8. In view of the fact that gas-forming organisms survive pasteurization which will give the preliminary test for the colon organism by the lactose bile fermentation-tube method, it seems advisable to suggest that boards of health which depend on the presence of the colon-aerogenes group as an indication of reinfection or inefficient pasteurization make a complete determination by cultural reactions of organisms suspected as being colon forms.

9. The thermal death point of one lactic acid organism isolated during this investigation was 79.4° C. (175° F.) when a broth culture was heated in Sternberg bulbs for 30 minutes. The thermal death points of 64 acid-forming bacteria from one sample of milk which

survived pasteurization for 30 minutes at 82.2° C. (180° F.) determined roughly was between 82.2° C. (180° F.) and 93.3° C. (200° F.).

10. Only a small percentage of spore-forming bacteria are found in milk pasteurized for 30 minutes at 62.8° C. (145° F.). Of 225 cultures selected at random which were studied, only 3, or 1.35 per cent, formed spores.

11. For those who advocate the inoculation of pasteurized milk after heating, with a culture of lactic acid bacteria to produce a normal souring, it is suggested that a culture of a high-temperature resisting lactic-acid organism may be added before pasteurization. By such a method there would be no danger of infection as might result accidentally by inoculation after pasteurization.

12. In view of the results of this investigation it seems that the control of pasteurization should be maintained by bacterial limits for the milk to be pasteurized, together with supervision which will insure the use of the proper pasteurizing temperature and guard against reinfection. A bacterial standard then need not be set for pasteurized milk.

CONCLUSIONS.

The results in this paper are based upon laboratory experiments performed under conditions which made reinfection impossible. The bacteria which survived pasteurization, therefore, represent those bacteria which could not be destroyed at the temperature of pasteurization. A temperature of 62.8° C. (145° F.) for 30 minutes was used in most of the experiments, since that is the most universally used temperature with the "holder" process in this country. Higher temperatures, however, were also used in order to show the changes in the bacterial groups which survived. From the results of the work it has been possible to show graphically in figure 29 the hypothetical relations of the bacterial groups in raw milk and milk pasteurized by the "holder" process at various temperatures under laboratory conditions. The bacterial flora of the various kinds of milk is represented by columns of equal length divided into sections, which represent in a general way the relative size of the bacterial groups.

From the figure it may be seen that raw milk contains four principal groups of bacteria—the acid, the inert, alkali, and peptonizing groups. The acid group is divided into two groups—the acid-coagulating, which coagulates milk in less than 14 days, and the acid group, which merely produces acid and does not coagulate milk inside of 14 days. In raw milk the inert group is the largest. In milk pasteurized at 62.8° C. (145° F.) the great increase in the proportion of the acid-coagulating and acid groups is plainly shown. The percentage of the alkali and peptonizing groups are reduced. At 71.1° C. (160° F.) the total acid group is still the largest, but the acid coagulating group is made up of bacteria which coagulate very slowly. At this temperature the alkali group is greatly reduced and the peptonizing reduced to the minimum. At 76.7° C. (170° F.) the total acid group remains about the same, but the organisms produce acid and coagulate very slowly. The alkali group is practically

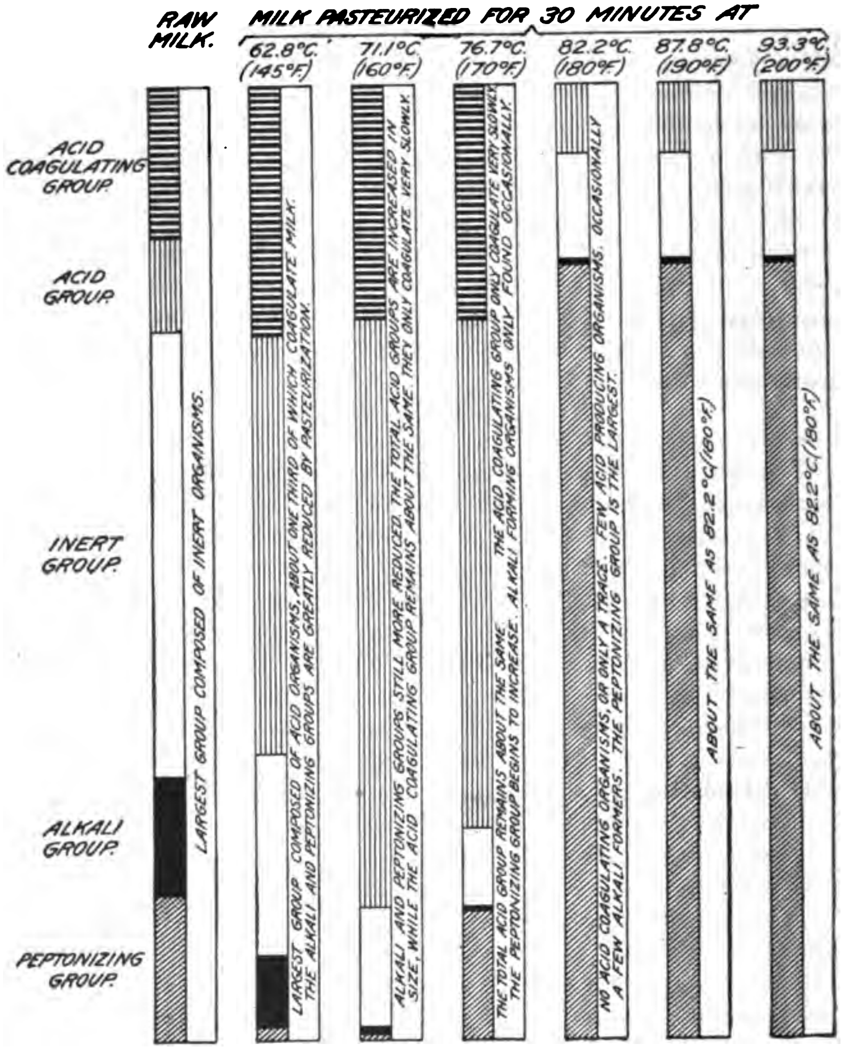

FIG. 29.—The hypothetical relation of the bacterial groups to raw and pasteurized milk.

destroyed, although occasionally a sample may show a fairly high percentage. The most important change is in the peptonizing group. At this temperature the percentage of the peptonizing group to the total bacteria begins to increase. The increase when milk is pasteurized at 82.2° C. (180° F.) is even more striking. At this temperature over 75 per cent of the bacteria which survive are peptonizers. None of the acid-coagulating group are found and only a small percentage of the acid group. Occasionally a few of the alkali group may be found. At 87.8° C. (190° F.) and 93.3° C.

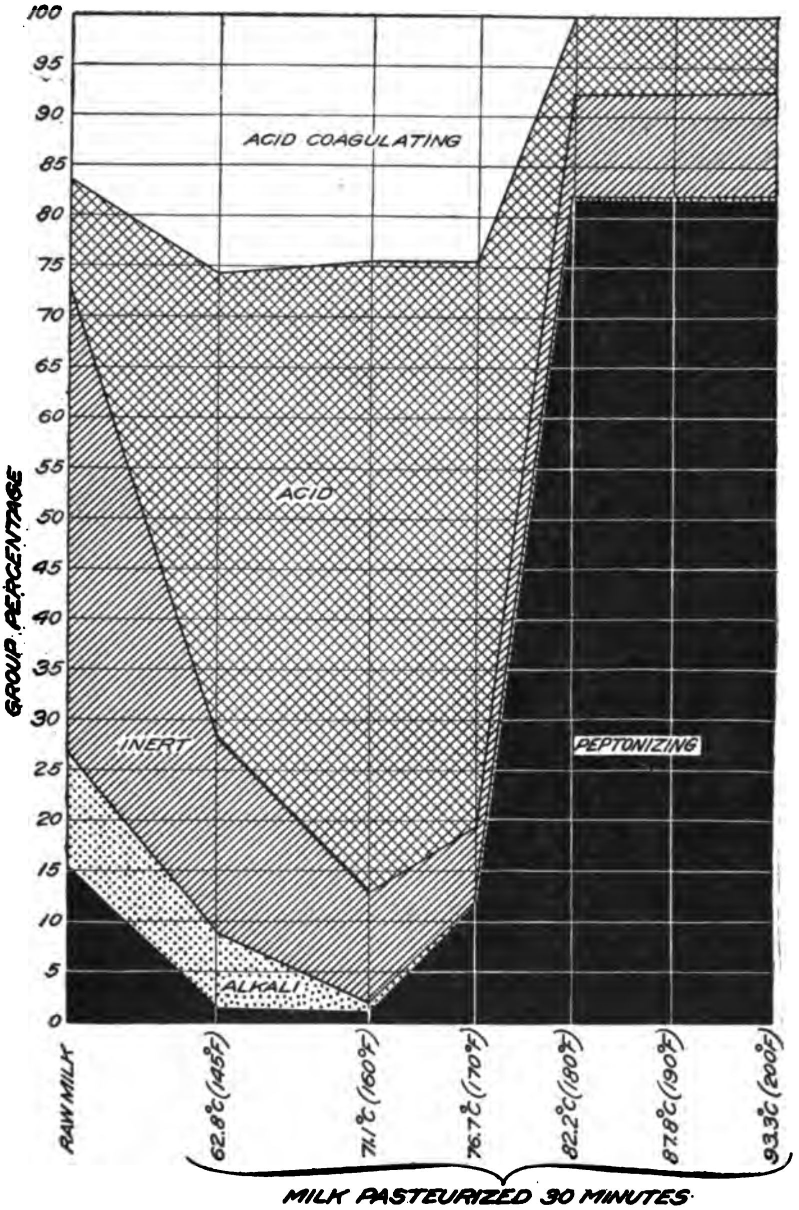

FIG. 30.—The hypothetical relation of the bacterial groups in raw and pasteurized milk.

(200° F.) the bacterial groups which survive are about the same in their relative sizes as at 82.2° C. (180° F.). The hypothetical relations of the bacterial groups are further shown in figure 30. The relation of the bacterial groups is also shown, which brings out more distinctly, perhaps, the changes in the bacterial groups. Here the reversal of the percentages of the total acid group and the peptonizing group in milk pasteurized above 76.7° C. (170° F.) for 30 minutes is plainly shown. It is very evident that when the bacterial flora of pasteurized milk is under discussion the temperature of the process is of fundamental importance. From these figures the bacterial groups in various kinds of milk may be seen at a glance, and they summarize in a very general way the most important results of this investigation. It must be remembered, however, that the relations of the bacterial groups only represent average conditions, and the bacterial flora of every sample of milk must not be expected to conform exactly to these averages. Variations in methods and conditions in the production of milk beyond the control of the investigator may widely influence the bacterial group relations of an individual sample.

APPENDIX.

TABLE I.—*Complete characteristics of the different varieties of acid-forming bacteria which survive pasteurization.*

Morphology.	Gram.	Gelatin, liquefied or nonliquefied.	Nitrate reduced.	Pigment.	Acid production in—									
					Dextrose.	Lactose.	Saccharose.	Galactose.	Mannite.	Glycerin.	Raffinose.	Inulin.	Starch.	Salicin.
C	+	−	−	−	+	+	−	+	−	−	−	−	−	−
C	+	−	−	−	+	+	−	+	−	−	−	−	−	+
C	+	−	+	−	+	+	−	+	−	−	−	−	+	+
C	+	−	−	−	+	+	−	+	−	+	−	−	−	+
C	+	−	+	−	+	+	−	+	−	+	−	−	−	−
C	+	−	−	−	+	+	−	+	+	−	−	−	−	+
C	+	−	+	−	+	+	−	+	+	−	−	−	+	−
C	+	−	±	−	+	+	+	+	−	−	−	−	−	−
C	+	−	±	−	+	+	+	+	−	−	−	−	+	−
C	+	−	±	−	+	+	+	+	−	−	−	−	−	+
C	+	−	±	−	+	+	+	+	−	+	−	−	−	−
C	+	−	−	−	+	+	+	+	−	+	−	−	−	+
C	+	−	−	−	+	+	+	+	−	−	+	−	−	−
C	+	−	−	−	+	+	+	+	−	−	+	−	+	−
C	+	−	−	−	+	+	+	+	−	−	+	−	−	+
C	+	−	−	−	+	+	+	+	−	−	−	+	+	−
C	+	−	−	−	+	+	+	+	−	−	+	+	+	−
C	+	−	−	−	+	+	+	+	−	−	+	+	+	+
C	+	−	±	−	+	+	+	+	+	−	−	−	+	−
C	+	−	−	−	+	+	+	+	+	−	−	−	−	+
C	+	−	−	−	+	+	+	+	+	−	+	+	−	−
C	+	−	+	−	+	+	+	+	+	−	−	−	−	−
C	−	−	−	−	+	+	+	+	+	+	+	−	−	+
C	+	+	+	−	+	+	+	+	−	+	−	−	−	−
C	+	+	+	−	+	+	+	+	−	−	−	−	−	−
C	+	+	+	−	+	+	+	+	+	+	−	−	−	−
C	+	+	−	−	+	+	+	+	+	−	−	−	−	−
C	+	−	±	+	+	+	−	+	−	−	−	−	−	−
C	+	−	−	+	+	+	−	+	−	−	−	−	−	+
C	+	−	−	+	+	+	−	+	−	−	−	−	+	−
C	+	−	−	+	+	+	−	+	−	−	−	−	+	+
C	+	−	+	+	+	+	−	+	−	−	+	−	−	−
C	+	−	+	+	+	+	−	+	−	+	−	−	−	−
C	+	−	+	+	+	+	−	+	+	−	−	−	+	−
C	+	−	±	+	+	+	+	+	−	−	−	−	−	−
C	±	−	−	+	+	+	+	+	−	−	−	−	+	−
C	+	−	±	+	+	+	+	+	−	−	−	−	−	+
C	+	−	−	+	+	+	+	+	−	−	−	−	+	+
C	+	−	−	+	+	+	+	+	−	+	−	−	+	−
C	+	−	+	+	+	+	+	+	−	+	−	−	−	−
C	+	−	±	+	+	+	+	+	−	−	+	−	−	−
C	+	−	+	+	+	+	+	+	−	+	+	−	−	+
C	+	−	−	+	+	+	+	+	+	−	−	−	−	−
C	+	−	±	+	+	+	+	+	+	−	−	−	+	−
C	+	−	−	+	+	+	+	+	+	−	−	−	−	+
C	+	−	+	+	+	+	+	+	+	−	−	−	+	+
C	+	−	+	+	+	+	+	+	+	−	+	−	+	−
C	+	−	−	+	+	+	+	+	+	−	+	−	+	+
B	+	+	+	−	+	+	+	+	−	+	−	−	−	−
B	+	−	−	[1]+	+	+	+	+	−	−	−	−	−	+
B	+	−	−	[1]+	+	+	+	+	+	−	−	−	+	+
B	+	−	−	[1]+	+	+	+	+	−	−	+	−	−	−

[1] Yellow.

TABLE II.—*Complete characteristics of the different varieties of alkali-forming bacteria which survive pasteurization.*

Morphology.	Gram.	Gelatin liquefied or nonliquefied.	Nitrate reduced.	Pigment.	Acid production in—										Alkaline reaction in litmus milk.
					Dextrose.	Lactose.	Saccharose.	Galactose.	Mannite.	Glycerin.	Raffinose.	Inulin.	Starch.	Salicin.	
C	+	−	−	−	−	−	−	−	−	−	−	−	−	−	+
C	+	−	−	[1]+	−	−	−	−	−	−	−	−	−	−	+
C	+	−	+	−	−	−	−	−	−	−	−	−	−	−	+
C	−	−	−	−	−	−	−	−	−	−	−	−	−	−	+
B	+	−	−	−	−	−	−	−	−	−	−	−	−	−	+
B	+	−	−	[1]+	−	−	−	−	−	−	−	−	−	−	+
B	+	−	+	−	−	−	−	−	−	−	−	−	−	−	+

[1] Yellow.

TABLE III.—*Complete characteristics of the different varieties of the peptonizing bacteria which survive pasteurization.*

Morphology.	Gram.	Gelatin, liquified or nonliquified.	Nitrate reduced.	Pigment.	Acid production in—										Casein peptonized.
					Dextrose.	Lactose.	Saccharose.	Galactose.	Mannite.	Glycerin.	Raffinose.	Inulin.	Starch.	Salicin.	
C	+	+	−	[1]+	+	+	+	−	−	−	−	−	−	−	
C	+	+	−	[2]+	+	+	+	+	−	+	−	−	+	−	
C	+	+	−	−	+	+	+	+	−	−	−	−	−	−	
C	+	+	−	[1]+	+	+	−	+	−	−	−	−	−	−	
C	+	+	−	[1]+	+	+	−	−	−	−	−	−	−	−	
C	+	+	−	[1]+	+	−	+	−	−	−	−	−	−	−	
C	+	+	+	[1]+	+	+	−	+	+	−	−	−	−	−	
C	+	+	+	−	+	+	−	+	+	−	−	−	−	−	
C	+	+	+	−	+	+	−	+	−	−	−	−	−	+	
C	+	+	+	[1]+	+	+	−	+	−	−	−	−	−	−	
C	+	+	+	[1]+	+	+	+	+	−	−	−	−	−	−	
C	+	+	+	[3]+	+	+	+	+	+	+	−	−	−	−	
C	+	+	+	[1]+	+	+	+	+	+	−	−	−	−	−	
C	+	+	+	−	+	+	−	+	−	−	−	−	−	−	
C	+	+	+	[1]+	+	−	+	+	−	+	−	−	+	+	
B	+	+	−	−	+	−	−	−	−	−	−	−	−	+	
B	+	+	−	−	+	−	+	+	+	+	−	−	−	+	
B	+	+	+	[1]+	+	−	+	+	−	+	+	−	+	+	
B	+	+	+	−	+	+	+	+	+	+	−	−	+	+	
B	+	+	+	−	+	−	−	−	−	−	−	−	−	−	
B	+	+	+	−	+	+	+	+	−	+	−	−	+	+	
B	+	+	+	−	+	−	+	−	−	+	−	−	+	+	
C	+	−	−	[1]+	−	−	−	−	−	−	−	−	−	−	+
C	+	−	−	[1]+	+	−	−	−	−	−	−	−	−	−	+
C	+	−	+	−	+	+	−	+	−	+	−	−	−	−	+
C	+	−	−	−	+	+	+	+	−	+	−	−	−	−	+
C	+	−	−	−	+	+	+	+	−	−	−	−	−	−	+
B	+	−	−	−	+	−	−	−	−	−	−	−	−	−	+
B	+	−	−	[1]+	+	+	−	−	−	−	−	−	+	−	+
B	[4]+	−	+	−	+	+	+	+	−	+	−	−	+	−	+
C	+	+	−	−	−	−	−	−	−	−	−	−	−	−	
C	+	+	−	[1]+	+	−	−	−	−	−	−	−	−	−	
C	+	+	+	[1]+	+	−	−	−	−	−	−	−	−	−	
B	+	+	−	−	−	−	−	−	−	−	−	−	−	−	
B	+	+	+	−	−	−	−	−	−	−	−	−	−	−	
B	−	+	+	−	−	−	−	−	−	−	−	−	−	−	
B	+	+	−	−	+	−	−	−	−	−	−	−	−	−	

[1] Yellow. [2] Brown. [3] Dark cream. [4] Spores.

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U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ANIMAL INDUSTRY.—BULLETIN 162.
A. D. MELVIN, CHIEF OF BUREAU.

FACTORS INFLUENCING THE CHANGE IN FLAVOR IN STORAGE BUTTER.

BY

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ANIMAL INDUSTRY,
Washington, D. C., October 8, 1912.

SIR: I have the honor to transmit herewith for publication in the bulletin series of this bureau a manuscript entitled "Factors Influencing the Change in Flavor in Storage Butter," by Messrs. L. A. Rogers, W. N. Berg, C. R. Potteiger, and B. J. Davis, of the Dairy Division.

Respectfully,

A. D. MELVIN,
Chief of Bureau.

Hon. JAMES WILSON,
Secretary of Agriculture.

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FACTORS INFLUENCING THE CHANGE IN FLAVOR IN STORAGE BUTTER.

INTRODUCTION.

The economic conditions in this country which have made it necessary to hold butter in storage for long periods have increased the importance of the changes that take place in butter on standing. A change that passes unnoticed in butter that is used when a week or two old may become a serious defect after three or four months in storage. The great variation and complexity of the changes in flavor indicate a corresponding complexity in the chemical alteration in the butter, and while it is true that some of the modifications are well known it is becoming evident that the various flavors are produced by changes too small to be measured by the ordinary methods of the laboratory. Under certain circumstances free fatty acids may be formed, a condition usually associated with a rancid flavor. However, it is evident that the fatty acids alone are not the cause of the rancid flavor, since, in the process of renovating, the rancid flavor is removed while a large part of the acid remains.

It is possible that the flavor-giving substances are produced in very small quantities and that their formation is not necessarily connected with or in proportion to the grosser changes measurable by the ordinary analytical methods. There are several substances in butter that are more or less unstable under ordinary circumstances, i. e., the proteins of milk in their hydrated condition, lecithin, citric acid, lactic acid, and other products of bacterial action. But little work has been done in which the storage flavor was shown to be related to chemical changes involving any of these substances. This is probably due to the fact that while butter fat is easily handled for analytical purposes, it is difficult to separate from the butter fat the other fatlike substances, such as lecithin. The remaining part of the butter, which will be called the butter curd solution, is of such a physical consistency that it can not very well be used directly for quantitative analytical work.

In considering the problem of storage flavor, its causes, and the methods of studying the problem, it is well to bear in mind one or two of the facts involved in the physiology of the senses of taste and smell. It is well known that several different substances may taste alike: Thus sugar, saccharin, lead acetate, glycerin, and perhaps still other substances, all taste sweet. Chemically they are not at all similar. While trimethylamin may be the specific cause of fishy flavor in herring brine, it is not necessarily the cause of fishy flavor in butter. It is possible, reasoning by analogy, that many different substances may cause "fishy" flavor.

The sense of smell is very delicate and can detect astonishingly small amounts of material, so small that the most delicate balances could not weigh them. A flavor is a mixed sensation in which the sense of taste and smell take a leading part. Howell[1] states that 0.00005 grams of quinine in 100 cubic centimeters of water is detectible on the root of the tongue. "It is recognized in chemical work, for instance, that traces of known substances too small to give the ordinary chemical reactions may be detected easily by the sense of smell. According to the experiments of Fischer and Penzoldt, mercaptan may be detected in a dilution of $\frac{1}{460,000,000}$ of a milligram in 50 cubic centimeters of air."[1]

While the off flavors of butter may not be caused by the formation of such inconceivably small amounts of odoriferous substances, yet such data are of practical significance in so far as they indicate that the analytical method of studying storage flavors may be wholly inadequate. There may be many substances[2] whose isolation or detection in butter might be very difficult if not impossible by present methods, and which would still impart to the butter sufficient odor and taste to be distinctly perceptible.

POSSIBLE CAUSES OF CHANGE.

The marked influence of bacteria on the flavor of milk, cheese, and other dairy products naturally leads to the conclusion that the same organisms would be an important if not the only factor concerned in the changes in butter. It has been demonstrated, particularly by the work of Jensen,[3] that under certain conditions bacteria multiply in butter and have a direct influence on the flavor of the product.

It should be remembered, however, that the butter on which Jensen and other European investigators worked differs in one very essential particular from the ordinary American butter. While the salt content of most European butter is low enough to permit the growth of bacteria, American butter contains sufficient salt to bring its concentration in the water of the butter to 18 per cent or more. It is to be expected that bacteria would not grow—or at least would grow only very sparsely—under these conditions, and the investigations in this country confirm this supposition. Rahn, Brown, and Smith[1] found in some samples of butter a torula able to grow very slowly in salt solutions at low temperatures, but this occurred in such small numbers that it could not account for much of the deterioration of the butter. In our own work we have found no evidence of bacterial growth under normal conditions, with the exception of a small multiplication of torula at high storage temperatures. In these cases there was no apparent relation between the growth of torula and change in flavor. Moreover, the same changes took place in duplicate lots of butter held at temperatures so far below the freezing point that there could be no possibility of growth. Any flavors that appear in butter may be found in butter held at the commercial storage temperature of zero or below (Fahrenheit), and any explanation of the cause of these changes which does not take this fact into consideration is obviously fallacious, or at best valid for certain conditions only.

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[1] Howell, William H. Textbook of Physiology. Philadelphia, 1906. See pp. 275–280.

[2] Zwaardemaker, H. Geruch. Ergebnisse der Physiologie. Abteilung 2, vol. 1, pp. 896–909. Wiesbaden, 1902.

[3] Jensen, Orla. Bakteriologische Studien über dänische Butter. Centralblatt für Bakteriologie, Parasitenkunde und Infektionskrankheiten. Abteilung 2, vol. 29, no. 23/25, pp. 610–616. Jena, Apr. 8, 1911.

Jensen, Orla. Studien über das Ranzigwerden der Butter. Centralblatt für Bakteriologie. Parasitenkunde und Infektionskrankheiten. Abteilung 2, vol. 8, no. 1, pp. 11–16, Jan. 4; no. 5, pp. 140–144, Feb. 5; no. 6, pp. 171–174, Feb. 10; no. 7, pp. 211–216, Feb. 17; no. 8, pp. 248–252, Feb. 24; no. 9, pp. 278–281, Mar. 4; no. 10, pp. 309–312, Mar. 8; no. 11, pp. 342–346, Mar. 13; no. 12, pp. 367–369, Mar. 15; no. 13, pp. 406–409, Mar. 24. Jena, 1902.

In some of our earlier work[2] the possible influence of lipolytic enzyms was suggested, but it was soon found that in many cases butter showed a marked change in flavor without any appreciable hydrolysis of the fat. This observation is confirmed by the work of Rahn, Brown, and Smith cited above. The action of other enzyms, as, for instance, the proteolytic enzym of the milk or those secreted by bacteria, is not necessarily excluded.

The influence of the acidity of the cream on the flavor of butter has already been pointed out.[3] It has also been suggested [4] that a slow oxidation may take place in the interior of a package of butter, due to the numerous small bubbles of air inclosed in the butter. Even a superficial examination of the work already done shows that the question is a very complicated one and that the difficulties in the way of a solution are many. In studying the ripening of cheese pronounced chemical changes are available for measuring the progress of the ripening. In butter the changes are scarcely appreciable. The investigator is thus forced to rely on the sense of taste and smell for a measure of the change. Some butter judges have developed marked ability in detecting and estimating the intensity of various flavors, but at best the sense of taste is uncertain, and any numerical scale based on this faculty is necessarily an arbitrary one and subject to fluctuation in its value. Two butter judges can not be expected always to agree, because the definitions of flavors can not be reduced to exact terms and the amount of deduction on the numerical scale for various flavors can not be fixed.

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[1] Rahn, Otto, Brown, C. W., and Smith, L. M. Keeping qualities of butter. Michigan Agricultural College Experiment Station, Technical Bulletin 2. East Lansing, September, 1909.

[2] Rogers, Lore A. Studies upon the keeping quality of butter. United States Department of Agriculture, Bureau of Animal Industry, Bulletin 57, Washington, 1904.

[3] Rogers, L. A., and Gray, C. E. The influence of acidity of cream on the flavor of butter. United States Department of Agriculture, Bureau of Animal Industry, Bulletin 114, Washington, 1909.

[4] Rogers, L. A. Fishy flavor in butter. United States Department of Agriculture, Bureau of Animal Industry, Circular 146, Washington, 1909.

The most serious difficulty in experimental work on butter is in controlling the conditions under which the butter is made. So many apparently unimportant factors have an influence on the flavor that it is nearly impossible to make butter with a normal flavor and have only one varying factor. The work is further complicated by the sequence of flavors that frequently occurs in butter held in storage. It is evident that the usual off flavors are in many cases a combination of flavors and that the flavors themselves are caused by a combination of circumstances and not by a single cause. It is probable also that identical flavors may be caused by different factors.

In the work reported in this paper we have attempted to determine the part played by certain factors in the general change in flavor in storage butter without directing the investigation toward any particular flavor or attempting to cover all of the causes of deterioration.

In this we have been guided by the previous work, which has indicated certain points at which the problem could be attacked with some promise of positive results. It has been observed, for instance, that when a lot of sweet cream is divided, one half churned at once and the other half pasteurized and churned, the butter from the unpasteurized half deteriorates very quickly, while the pasteurized-cream butter has exceptionally good keeping qualities. What has been removed by the pasteurization that has such a marked influence on the butter? The enzyms of the milk are partly or entirely destroyed and a large proportion of the bacteria are killed. Are the proteolytic enzyms of the milk able to work under the conditions existing in butter and have they any influence on the flavor of the butter? Is there any appreciable proteolysis in butter even under favorable conditions? If the two lots of cream are ripened, the keeping quality of the butter from the unpasteurized cream is increased, while that from the pasteurized cream is decreased. In the process of ripening the bacterial growth is confined almost entirely to one variety, but it does not necessarily follow that these bacteria have any direct deleterious action. The growth of the bacteria produces a considerable quantity of acid, and the chemical instability of the product is increased accordingly.

Does the air which, as has been shown, is inclosed in the butter effect an appreciable oxidation? Milk and cream is handled in containers in which it may be exposed to tin, iron, or copper. Under these conditions it is reasonable to suppose that small amounts of the metals, especially the iron and copper, will be dissolved and carried into the butter. Do the salts formed by the metals with organic acids of the cream affect the flavor of the butter?

PROTEOLYSIS IN BUTTER.

It has long been known that butter differs from milk in its composition only in the relative amounts of the constituents present in the two. Among these constituents which early attracted attention as possible causes of storage flavor because of their chemical instability were the proteins, mainly casein. Proteins in the hydrated or moist condition in the presence of water are known to be unstable, and it is but natural that these substances, wherever they may occur in food, should be looked upon as possible sources of off flavor. It is almost certain that in butter containing no salt, or salt in an insufficient amount, or in butter that is not stored at sufficiently low temperature, the proteins present do undergo hydrolysis and perhaps putrefaction and other obscure changes as well. But the present work does not concern itself with such material. The problem is: If storage flavor develops in butter properly made and properly stored, do the proteins contribute in any way toward this off flavor?

Certain conditions in butter favor proteolytic changes, namely, the presence of water, bacteria, and of the proteolytic enzym known as galactase, which occurs normally in milk. Other conditions, as low temperature, the presence of sodium chlorid, the partial inactivation of the galactase by pasteurization, tend to prevent or retard proteolytic changes.

It has already been shown by other investigators that under conditions of comparatively high temperature and low salt the butter proteins will undergo changes. In the present work an attempt was made to determine whether the galactase present in butter made from pasteurized or from unpasteurized cream can digest casein in spite of the retarding influence of low temperature and high salt concentration.

PREVIOUS WORK.

Analytical difficulties.—When butter is melted and allowed to stand, the water present, containing the salt and casein in solution and in suspension, will settle to the bottom of the container, leaving the supernatant fat clear. The fat may be poured off and filtered if desired and at once used for quantitative work. However, all of the fat can not be poured off, because part of it is thoroughly mixed with the particles of curd, so that after the most careful removal of fat by decantation a considerable amount is still left. Some of this residual fat can be removed by the addition of ether. This will dissolve the fat on the upper surface of the curd solution and permit more fat to rise; but even three or four such washings with ether still leaves in the curd solution a considerable quantity of fat, probably 20 grams of fat in 100 cubic centimeters of curd solution. It is obvious that such a mixture of fat, sodium chlorid solution, and casein suspension is not very well adapted to quantitative work. The material will not filter, nor can small samples of uniform composition be easily withdrawn from it.

In order to study the possible changes in the proteins of butter, this is the material to be used. In principle, the method of testing for the presence of active proteolytic enzyms in this material is no different from that used for other purposes, as, for instance, in tracing the proteolytic changes in ripening cheese or in animal tissue undergoing autolysis. At first it would seem as if there should be no difficulty in making the usual nitrogen partition in this curd solution just as it is made on other viscous mixtures that are equally difficult to filter and sample.

Evidently it was at the first step in the nitrogen partition that the difficulties began, for, to the best of our knowledge, none of the previous investigators succeeded in precipitating the casein in the curd solution, filtering and determining nitrogen in the filtrate or the precipitate, in such a manner as to enable the investigator to draw safe conclusions from the analytic data thus obtained. To this statement there are apparent exceptions. On adding acetic acid in usual amounts to some of the curd solution as if it were so much milk for the purpose of flocculating the casein and filtering no flocculation is seen to occur and the mixture will filter so slowly as to make quantitative work unreliable for obvious reasons. If the curd solution be diluted with water until the casein can be flocculated by acetic acid in usual amounts, filtration is then rapid and the filtrate can then be used for nitrogen determinations. The nitrogenous substances in butter, however, are about 75 per cent casein, so that on removal of the casein there is so little nitrogen left in the filtrate from the diluted curd solution that the unavoidable errors in such work are very large when compared with the analytic data obtained. Still less certain are the results obtained on the nitrogen partition in such a filtrate, because the total nitrogen is too small for even that determination.

In order to avoid the introduction of comparatively large errors, we made many attempts to increase the amount of curd solution used and to reduce the dilution before adding the precipitant. Acetic or other acids evidently were not previously used in quantities sufficient to flocculate the casein. Other precipitants, such as ferric chlorid, phosphotungstic acid, tannic acid, copper sulfate, etc., were tried. When added to curd solutions diluted with but two volumes of water, these precipitants will thoroughly flocculate the protein and give a filtrate that is clear, comes through rapidly, and can be used for quantitative work. Unfortunately, these precipitants remove from the curd solution practically all of the nitrogen, leaving too little in the filtrate. The water-soluble nitrogen in good butter is approximately one-fifth to one-tenth of the total, and in so far as the total nitrogen is represented by 1 per cent of curd, or about 0.1 to 0.2 per cent of nitrogen, it is necessary to use large amounts of curd solution for these precipitations in order that the filtrates may contain sufficient nitrogen for accurate determinations.

Results by Gray and others.—Several years ago (1906) Mr. C. E. Gray, then connected with the Dairy Division, began a study of the possible proteolytic changes in storage butter and their relation to the change in flavor. Following is his method of making the partition of nitrogen in butter:

Total nitrogen.—Introduce 10 grams of butter into a Kjeldahl flask, digest, and distill as usual.

To obtain nitrogen in other forms: Melt 2 kilos of butter in a hot-water jacketed funnel, temperature about 80° C. The melted butter is allowed to run into a cream separator with a special bowl having a capacity of 700 cubic centimeters without milk outlets. This was just large enough to hold all of the curd solution plus a small amount of fat. As the butter was fed in the bowl soon became filled and the excess of butter fat ran out, leaving the curd solution in the bowl. The larger part of the fat was washed out by feeding gasoline into the bowl. The last portion of gasoline was removed by feeding in water. The addition of water was stopped as soon as the outflowing liquid carried particles of casein. In this way the curd solution in 2,000 grams of butter was separated from most of the fat. The contents of the bowl were transferred to a 1-liter flask, 25 cubic centimeters of 10 per cent ferric chlorid solution were added, and the total volume made up to the mark. The mixture was filtered on a 32-centimeter filter and the faintly colored filtrate used in the following determinations. Although but 600 to 700 cubic centimeters of filtrate were obtained, the results on aliquot portions were always calculated to 1,000 cubic centimeters.

It is obvious that these filtrates contained only nitrogen not precipitated by ferric chlorid; that is, nitrogen largely in the form of amino acids and ammonia. Certain peptones are precipitated by ferric chlorid.[1]

Total soluble nitrogen.—Transfer 50 cubic centimeter portions of the filtrate (corresponding to 100 grams of butter) to Kjeldahl flasks and determine total nitrogen.

"*Amino and ammonia nitrogen.*"—Transfer a 200 cubic centimeter portion of the ferric chlorid filtrate to a 300 cubic centimeter volumetric flask. Add 1 gram of sodium chlorid and sufficient 12 per cent tannic acid solution for maximal precipitation. Three or four cubic centimeters were usually required. Make up to the mark with distilled water, filter, and determine total nitrogen in 100 cubic centimeter portions of the filtrate, each of which corresponds to 133⅓ grams of butter.

"*Ammonia nitrogen.*"—The method described by Van Slyke and Hart[2] was used.

Transfer 100 cubic centimeters of the ferric-chlorid filtrate (corresponding to 200 grams of butter) to a Kjeldahl flask, add 2 grams of magnesium oxid, and boil for about 1½ hours, catching the distillate in N/20 acid. The excess of acid was titrated in the usual way.

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[1] Siegfried, M. Zur Kenntniss der Phosphorfleischsäure. Zeitschrift für Physiologische Chemie, vol. 21, no. 5/6, pp. 360–379. Strassburg, Apr. 2, 1896.

Siegfried, M. Ueber Antipepton. Zeitschrift für Physiologische Chemie, vol. 27, no. 4/5, pp. 335–347. Strassburg, June 24, 1889. See p. 342.

[2] Van Slyke, L. L., and Hart, E. B. Methods for the estimation of the proteolytic compounds contained in cheese and milk. New York Agricultural Experiment Station, Bulletin 215, Geneva, September, 1902.

Amino nitrogen is the difference between the sum of the amino and ammonia nitrogen and the ammonia nitrogen.

Proteose and peptone nitrogen is the difference between the total soluble nitrogen and the sum of the amino and ammonia nitrogen.

This method of studying the distribution of nitrogen in butter was used by Gray from 1906 to 1907 on a very large number of samples of butter churned from ripened, unripened, pasteurized, and unpasteurized cream and stored at various temperatures. The plan of the investigation was very comprehensive. It aimed to ascertain the best conditions for the production of butter of best keeping quality and the chemical changes causing the off flavors of storage butter. This method was also used by us on one series of 24 samples in the spring of 1908.

Gray's method of removing most of the fat from the butter by the use of the centrifuge was an improvement, without doubt. But for reasons to be made apparent presently the analytic data obtained by this method were not regarded as conclusive. More accurate data, it is believed, were later obtained by a method that is free from some of the objections that might be made to the method as originally devised by Gray.

In Table 1 are some results obtained by Gray. The butter was obtained from one lot of cream which was divided into eight portions from which eight separate churnings were made. The eight lots of butter were packed in 20-pound tubs and stored soon after churning, at −10° F. (−23° C.). Analyses were made on the fresh butter, representing the condition of the nitrogen in the butter before storage. The two following series of analyses were made on the butter after different periods in storage. Two similar series of results were obtained by Gray on portions of the same lots of butter, stored at 10° F. (−12° C.) and at 32° F. (0° C.). The figures are not given here, but are in general similar to those in Table 1.

From the results obtained by Gray it would seem that in the samples of butter examined slow proteolytic changes took place during storage. At least this is the inference to be drawn on the assumption that the method of obtaining the chemical data was free from avoidable errors.

TABLE 1.—*Changes in the distribution of nitrogen in butter during cold storage* (−10° F., −23° C.).

Butter No.	Age of sample.	Total nitrogen.	Total soluble nitrogen.	Proteose and peptone nitrogen.	Amino nitrogen.	Ammonia nitrogen.
	Days.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
10.311	0	0.136	0.0039	0.0013	0.0019	0.00074
	206	....	.0070	.0032	.0028	.00095
	298	....	.0083	.0043	.0030	.00105
10.312	0	.139	.0041	.0026	.0006	.00091
	206	....	.0065	.0035	.0021	.00095
	298	....	.0074	.0026	.0039	.00095
10.313	0	.139	.0053	.0003	.0037	.00130
	206	....	.0067	.0032	.0022	.00134
	298	....	.0071	.0041	.0017	.00131
10.314	0	.143	.0045	.0005	.0028	.00115
	206	....	.0061	.0023	.0025	.00132
	298	....	.0090	.0046	.0031	.00128
10.321	0	.140	.0020	....	.0018	.00058
	206	....	.0037	.0014	.0016	.00066
	298	....	.0073	.0052	.0014	.00070
10.322	0	.138	.0030	....	.0030	.00053
	206	....	.0053	.0021	.0036	.00061
	298	....	.0035	.0007	.0022	.00062
10.323	0	.139	.0037	.0003	.0029	.00049
	206	....	.0047	....	.0050	.00066
	298	....	.0061	.0034	.0030	.00062
10.324	0	.141	.0065	.0007	.0049	.00087
	206	....	.0081	.0024	.0048	.00088
	298	....	.0087	.0068	.0010	.00086

The method of Gray in a slightly modified form was used in the summer of 1908 and the spring of 1909. The results obtained were, in general, similar to those obtained by Gray. They seemed to indicate that slow proteolysis was taking place.

After using the method for a short time several improvements suggested themselves. It will be noticed in Table 1 that the largest amount of nitrogen estimated in a ferric-chlorid filtrate (column headed "total soluble nitrogen") was equivalent to 0.009 per cent of nitrogen in the butter, or to 6.3 cubic centimeters N/10 nitrogen. This is not a large amount. The largest difference between total soluble nitrogen before and after storage in Table 1 is that for sample 10.321, and is equivalent to not quite 4 cubic centimeters N/10 nitrogen. It seemed desirable so to change the method as to increase the amounts of nitrogen actually estimated. Whether proteolysis did or did not take place would then be decided with the aid of figures that are not so small that the unavoidable errors in such work are comparatively large. Filtration was so slow that evaporation undoubtedly took place to an unnecessarily large extent. The analyst could not be certain that 100 cubic centimeters of a ferric-chlorid filtrate obtained after storage corresponded to exactly the same weight of butter as an equal volume of filtrate obtained before storage. Either filtration must be so rapid that evaporation may be disregarded because of its slight extent, or if filtration must be slow the volumes of filtrates should be carefully measured, so that the weight of butter corresponding to any volume of filtrate can be definitely ascertained.

Objections to ferric chlorid and tannic acid as protein precipitants.—Ferric chlorid as a protein precipitant was not wholly desirable because, as here used, it precipitated not alone the casein and other undigested proteins, but their immediate digestion products down to the peptone stage. The "ferric-chlorid filtrate" probably does not contain proteoses. The use of the term "total soluble nitrogen" in this connection will lead to no confusion if it be borne in mind that it means nitrogen not precipitated by ferric chlorid. The figures for "proteose and peptone nitrogen" in Table 1 probably represent only some of the simpler peptones. The amount of nitrogen left in the ferric-chlorid filtrate is small, at least, when used for the separation of the different forms of nitrogen in butter-curd solution.

Tannic acid as a protein precipitant is perhaps still more objectionable than ferric chlorid. It is well known that the precipitation limits of tannic acid may be varied by the presence of salts, etc. Two results obtained with the aid of tannic acids are comparable only when the precipitant has been used in both cases under conditions that are exactly alike as regards the concentration of sodium chlorid, the amount of protein to be precipitated, the precipitating power of the samples of tannic acid used, etc.[1] The greatest care must be taken in the use of the reagent to insure absolute uniformity in procedure. This is shown by the voluminous literature on the use of this reagent, in which the numerous difficulties and necessary modifications are pointed out.

In addition to the difficulties just mentioned are those resulting from differences of opinion among investigators as to the best method of using the reagent. Van Slyke and Hart,[2] in their determinations of peptones in cheese are extremely careful to avoid an excess of tannic acid, probably because of the alleged solubility of the precipitate in excess of the precipitant.

According to Bigelow and Cook [3]—

> * * * a considerable excess of tannin may be employed without any tendency of the reagent to dissolve the precipitate formed in excess. * * *

Gray used tannic acid as directed by Van Slyke and Hart.

It is not surprising that certain workers should advocate the discontinuance of the use of tannic acid as a reagent for the determination of amino acid nitrogen.[4]

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[1] Bigelow, W. D., and Cook, F. C. The separation of proteoses and peptones from the simpler amino bodies. Journal of the American Chemical Society, vol. 28, no. 10, pp. 1485-1499. Easton, October, 1906.

[2] Loc. cit.

[3] Loc. cit., p. 1493.

[4] Proceedings of the Twenty-sixth annual convention of the Association of Official Agricultural Chemists, United States Department of Agriculture, Bureau of Chemistry, Bulletin 132. Washington, 1910. See p. 156.

The results obtained by Gray for amino nitrogen in Table 1 are not concordant, probably due to difficulties inherent in the use of tannic acid. Our own results are likewise difficult to interpret. In a certain series of analyses (butter No. 13.5) less amino nitrogen was found in the butter after storage than before. The figures are not given here, as they are essentially similar to those of Gray.

After obtaining a considerable number of results on the distribution of nitrogen in butter before and after storage, with the aid of ferric chlorid and tannic acid, we were unable to conclude that the results proved anything. It seemed more and more desirable to perfect a method that would permit the precipitation of the casein, then the estimation of proteoses by zinc sulfate, peptones by tannic acid, and ammonia by any of the methods that did not give too high results.

In order to obtain a filtrate containing sufficient nitrogen for analytic work, the curd solution can not be diluted very much. In the undiluted condition it is a thick, viscous suspension of casein containing a variable amount of fat to which acetic acid may be added without any apparent effect. No flocculation can be observed. The mixture would filter extremely slowly. We made many attempts to find out why filtration was so slow. At first it was thought that fat particles clogged the filter paper. The first attempts were centered on the more thorough separation of the butter fat from the remainder of the butter, which in this paper is referred to as butter curd solution. It is obvious that unless the same amount of fat is removed in comparative analyses of butter before and after storage, an error will be introduced because the fat remains in the precipitate, giving a smaller volume of more concentrated filtrate. The error from this source is probably much larger than anyone might suppose. The amount of fat present in the butter curd solution used for analytical purposes should be estimated so that corrections can be made if necessary.

The butter fat may be separated from the remainder of the butter in more than one way. But obviously, when the curd solution and not the fat is wanted for quantitative work, the separation must consist of something more than a mere decantation of the melted fat. The butter fat and curd are so thoroughly mixed in the butter that when the butter is melted and allowed to stand, the separation between fat and curd solution is not complete. Most of the fat can be decanted, but very appreciable amounts still remain in the curd. Although Gray attempted to wash out the fat with the aid of gasoline, it is certain that very much fat was still present in the material used for analysis. We tried to remove the fat with ether, but without success. The fat particles are embedded in curd and in this condition ether can not reach them. Besides, the ether could only be poured on top of the curd solution. Thorough mixing was inadvisable because of the possibility of forming emulsions that could not be separated. The use of ether was soon discontinued because of the possible dehydrating action of the ether upon the protein material and the subsequent obscuring of the results for nitrogen. The complete separation of fat from curd solution was then abandoned with the intention of estimating the amounts of fat present in portions used for analysis. In their work on storage butter, Rahn, Brown, and Smith [1] did not record a quantitative separation of butter fat from curd solution. Instead, they proceeded as follows:

> Into a weighed 2-quart [fruit] jar about 500 grams of butter were poured and weighed to the 0.5 of a gram. Then 2 grams of hot water (70° C. to 75° C.) for every gram of butter was poured into the jar and the water and butter stirred occasionally for about an hour. The cover to which an arrangement for letting in air and drawing off water had been attached was put on and the jar inverted. After 15 or 20 minutes the water which had been separated from the fat was drawn off. Aliquot parts were taken for analysis.

One objection to such a procedure lies in the fact that the water so separated from the fat contains too little nitrogen. The analytic data of Rahn, Brown, and Smith on nitrogen partition in butter are open to the same criticism as are Gray's data in Table 1. Their results differ little from those of Gray. Their work did not assist in explaining why acetic acid will flocculate casein in milk, but not in butter curd solution. This problem had been evaded by practically all who studied butter chemistry.

In a recent investigation on the influence of preservatives on the keeping qualities and composition of butter and oleomargarin, Fischer and Gruenert [2] used the methods of Rahn, Brown, and Smith in their studies on proteolytic changes. They state that the addition of 3 per cent of salt to butter greatly retards, but does not entirely prevent, proteolytic and other changes in butter stored in a cool cellar.

NEW METHOD FOR DETECTING PROTEOLYSIS IN BUTTER.

The influence of sodium chlorid on the precipitability of casein by acetic acid.—Butter curd solution differs from milk in many respects; one of them is that butter curd solution may contain sodium chlorid in amounts ranging from nothing up to saturation (over 30 per cent), depending upon the moisture and salt content of the butter. Perhaps the presence of the salt prevented flocculation of casein.

During a previous investigation on the temperature of pasteurization for butter making [3] the following method of precipitating casein from buttermilk, milk, or skim milk was used. The object was to obtain a filtrate that was as concentrated in nitrogen as possible, and from which the casein had been quantitatively separated:

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[1] Loc. cit., p. 14.

[2] Fischer, K., and Gruenert, O. Über den einfluss einiger Konservierungsmittel auf Haltbarkeit und Zusammensetzung von Butter und Margarine. Zeitschrift für Untersuchung der Nahrungs- und Genussmittel, vol. 22, no. 10, pp. 553–582, Berlin, Nov. 15, 1911.

[3] Rogers, L. A., Berg, W. N., and Davis, Brooke J. The temperature of pasteurization for buttermaking. United States Department of Agriculture, Bureau of Animal Industry, Circular 189, Washington, 1912. See p. 317.

Transfer 200 cubic centimeters of buttermilk to a 500 cubic centimeter volumetric flask. Add distilled water to about 450 cubic centimeters. Add one-fifth normal acetic acid (1.2 per cent) slowly until the casein separates completely in large flocculi leaving the supernatant liquid practically water-clear. In practically every case 44 cubic centimeters of N/5 acetic acid was used and found sufficient for the purpose. After diluting to the mark and filtering, nitrogen determinations were made on the filtrate.

The questions to be studied now were: Would the presence of salt in milk prevent the flocculation of the casein and the subsequent attempt at filtration?

In a sample of skim milk from which the casein can be easily flocculated and filtered would the presence of added fat interfere with filtration?

Results were almost immediately obtained which threw a great deal of light on the difficulty. The following experiment is typical:

Two hundred cubic centimeters of buttermilk obtained from a churning of pasteurized cream were transferred to a 500 cubic centimeter volumetric flask. Water was added to about 400 cubic centimeters. On slowly adding 85 cubic centimeters N/10 acetic acid (0.6 per cent) the casein was completely flocculated. To a second 500 cubic centimeter volumetric flask 200 cubic centimeters of the same sample of buttermilk was transferred. Thirty-six grams of sodium chlorid were added. This concentration of approximately 18 per cent is the concentration of salt in butter curd solution when the butter contains 16 per cent moisture and 3 per cent salt. Water was added, as before, to about 400 cubic centimeters. The addition of 85 cubic centimeters N/10 acetic acid as before did not flocculate the casein.

This experiment showed that the presence of salt very materially affected the precipitability of the casein. This was clearly a case where the physical condition of a colloid was so altered by the presence of large amounts of electrolytes that it did not react toward a precipitant as it usually does. The acetic acid added certainly was not in excess. The slow addition of the acid without at any time resulting in even a partial precipitation of casein indicated that more acid was required. After adding 40 cubic centimeters more of N/10 acetic acid, without any signs of flocculation, 10 per cent acetic acid (5/3 normal) was carefully added instead of the weaker N/10 acid. After adding 11 cubic centimeters of 10 per cent acetic acid, the casein was completely flocculated, and the mixture could be filtered rapidly, yielding a perfectly clear filtrate.

In the presence of salt 300 cubic centimeters N/10 acetic acid were required for the precipitation of casein, which in the absence of salt would have been precipitated by 85 cubic centimeters of N/10 acetic acid. It is probable that observations of a somewhat similar nature were simultaneously made by other investigators, as is evident from the following quotation from a paper by Schryver[1] which appeared a few months after the above-described experiment was made:

> During the course of some investigations on the action of formaldehyde on the proteins, the observation was made that this aldehyde, when added to an aqueous solution of Witte's peptone, produces a precipitate, and that the reaction could be either partially or completely inhibited by the presence of neutral salts. This phenomenon was also noticed some years ago by T. Sollman (American Journal of Physiology, 1902, vol. 7, p. 220). * * *

Besides being extremely interesting theoretically, the observation just made on the effect of salt on the precipitation of casein was of interest practically because of its possible application to the separation of casein from butter curd solution. The theoretical side of the phenomenon is discussed by Schryver in the above-mentioned paper.

Method for the estimation of water-soluble nitrogen in butter.—After numerous experiments the following procedure was adopted for the separation of the fat from the butter curd solution to be used for nitrogen determinations. As the method was new, many precautions were taken, some of which were later found to be unnecessary. This method of separating fat and casein from butter yields a filtrate that is well adapted, not alone to a study of the nitrogenous constituents of the filtrate, but to many other purposes as well. The filtrate, for example, contains the peroxidase which is practically always present in butter.

To two or three large beakers, capacity 2 to 2½ liters, transfer 5 to 6 kilograms of the sample of butter to be studied. Two samples (one from raw, one from pasteurized cream, for example) may be worked with at one time. The larger the amount of butter taken the better. Place the beakers, properly marked, in a hot-air bath maintained at about 45° C. If the butter to be stored is packed in cans, five or six 2-pound cans are placed in the hot-air bath to be melted. In the work here described the cans were taken out of the ice box late in the afternoon, allowed to warm up during the night at room temperature, and placed the next morning in the air bath, the temperature of which varied usually 2° above and below 45° C. The temperature should not be permitted to rise much beyond 45° C., because of the danger of coagulating some of the protein present. The high temperature at which Gray and Rahn, Brown and Smith (see pp. 11, 16) melted their samples of butter undoubtedly removed, by coagulation, comparatively large amounts of nitrogen from their filtrates.

At this temperature from six to eight hours will be required for the complete melting of the butter and the settling of the curd solution. Stirring does little good. As fast as the butter fat forms a clear layer on top of the butter it may be poured off, care being taken that none of the curd solution is lost at any time. The loss of a few small particles of solid protein is not material. This long heating at a temperature that is perhaps best for proteolytic action is an objection to the method. It will be apparent, however, that the error introduced in this way is inappreciable. (See p. 20.)

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[1] Schryver, S. B. Some investigations dealing with the state of aggregation of matter. Proceedings of the Royal Society, London, series B, vol. 83, no. B562, pp. 96-123. London, Dec. 19, 1910. See p. 96.

The melted butter fat is decanted until no more can be so removed without danger of losing some of the curd solution. With the aid of a 100 cubic centimeter pipette having its lower tip cut off to permit more rapid flow of viscous materials, remove the curd solution from the bottom of the beaker or can and transfer it to a dry, clean, 500 cubic centimeter volumetric flask. Considerable fat will, of course be mixed with the curd solution, but by taking only part from the bottom of each vessel sufficient curd solution will be obtained from 5 kilograms of butter to fill two 500 cubic centimeter flasks. Let stand till the next morning at room temperature. With the aid of a rapid-flow 100 cubic centimeter pipette, remove from the bottom of each of these flasks between 200 and 250 cubic centimeters of curd solution and transfer this to a clean, dry, 500 cubic centimeter volumetric flask. From the original 5 kilograms of butter there have now been separated not quite 500 cubic centimeters of curd solution containing approximately 10 per cent of fat. The rest of the curd solution containing much larger proportions of fat may be rejected.

In a separate portion of the original sample of butter, determine moisture, curd, and salt. For this purpose the methods described in Bulletin 107 (revised edition), Bureau of Chemistry, page 123, were used. From these figures the weight of butter corresponding to a given volume of curd solution may be calculated if desired, but for the present work such calculation was not necessary.

The curd solution should be well mixed, and then with the aid of a rapid-flow pipette a portion is transferred to a pycnometer (50 cubic centimeters capacity) and the weight ascertained. The object of this determination is to make certain that the curd solution used for analysis before and after storage of butter is practically the same so far as the density of the material is concerned. It is obvious that if the proportion of fat and salt solution differs very much in two samples of curd solution obtained from the same lot of butter before and after storage the specific gravity will be different. This determination, when repeated on the same portion of curd solution, will show that it is possible to withdraw samples of uniform composition from the flask if care be taken to mix the contents well and to withdraw the sample rapidly before the fat rises to any appreciable extent.

Portions of this curd solution may now be withdrawn for nitrogen determinations. To several clean, dry, 500 cubic centimeter volumetric flasks transfer 100 cubic centimeter portions of curd solution, using a rapid-flow pipette and sampling quickly. This is the amount found most convenient when acetic acid is to be used as a precipitant. When other precipitants, such as ferric chlorid, are to be used, a larger volume may be taken.

In our work we generally made three and sometimes four determinations on a single sample of butter, although two are perhaps sufficient. Each 100 cubic centimeter portion was used for one determination, so that as many such portions are to be pipetted into 500 cubic centimeter flasks as determinations are wanted. (See Table 2.) In the remainder of the curd solution we determined fat by removing 10 cubic centimeter portions, transferring to absorbent paper, drying at the temperature of boiling water, and extracting the fat in a Soxhlet apparatus, as usual. These figures for fat are for the purpose of control only, and indicate how much of the volume of the portion of curd solution is taken up by fat.

The undiluted curd solution may be allowed to remain in the stoppered flasks for 24 or 48 hours at room temperature without any apparent change in the results. In several cases even a week's standing was without effect. The concentration of salt is usually high enough to make the addition of other preservatives unnecessary. Under these conditions the proteolytic enzym present, galactase, is not very active; at least, on standing several days practically the same results are obtained as on freshly prepared curd solution.

The curd solution is diluted to about 450 cubic centimeters with distilled water, mixed well and then 10 per cent acetic acid is added slowly, with constant mixing of the contents of the flask. It is obvious that sufficient acetic acid must be added to completely precipitate the casein in the flocculent condition. This will occur generally when 18 to 22 cubic centimeters have been added. The curd solutions from pasteurized cream butter generally require the larger amount for flocculation. In Table 2 the amounts of acetic acid used are indicated. It seems that the more fat present the more slowly does the casein flocculate. On standing about 15 minutes the casein will be seen to have flocculated. The amount of acetic acid added should be recorded so that that same amount can be used after storage. In fact, all data should be recorded that might be necessary for the purpose of duplicating the determination exactly after storage. Dilute with distilled water to the mark and filter on a 32 centimeter folded filter (S. & S. No. 588 or 595) into a clean, dry, 500 cubic centimeter volumetric flask. The curd solutions should not be allowed to stand long after the addition of water. The filter stands, clean funnels, and flasks were in readiness before the addition of water and acid to the curd solutions, so that filtration was begun within a very few minutes. The entire contents of the flask were transferred to the filter paper. If the filtrate at first was cloudy, it was returned to the filter as often as necessary. Usually the first portions of filtrate, about 50 cubic centimeters each, were returned to the filter two or three times. In no case was a filtrate used for nitrogen determinations that was so cloudy as to indicate the presence of unprecipitated casein. Usually the filtration was begun in the afternoon and allowed to go on till the next morning. The funnel was covered with a well-fitting watch glass to minimize evaporation.

On several occasions the precipitate on the filter paper was examined at the end of the filtration for peptonizing bacteria. Such small numbers were found that their effect was inappreciable. It is obvious that the digestion of protein on the filter paper by bacteria or their enzymes might vitiate the results. We have no reason to believe that in any of the results appreciable errors were introduced in this way.

The amount of acetic acid was varied a little when precipitating the casein from different portions of the same curd solution in order to find out whether, under the conditions of the work, small variations in the amount of acetic acid would give rise to undesirably large variations in the results. Of course, if insufficient acetic acid is added all of the casein will not be precipitated and the mixture will filter so very slowly that that alone will indicate incomplete precipitation. The more completely the casein is precipitated the more rapid is the filtration. Slight excesses of acetic acid apparently have an inappreciably small solvent action on the precipitate. It is true that in precipitating casein from diluted milk an excess of even very dilute acetic acid is undesirable. In the presence of the sodium chlorid, however, conditions are so altered that the solvent action of the acetic acid is apparently very much diminished. In case of doubt, more rather than less acetic acid was used.

The clear, slightly opalescent filtrate may be tested for completeness of precipitation by the addition of more acid or of alkali. In no case did the addition of small amounts of acid or of alkali (N/10) to the filtrate result in the precipitation of protein. If sufficient alkali was added to make the filtrate alkaline to phenolphthalein, a precipitate was obtained which was probably calcium phosphate containing adsorbed protein. In appearance it resembled some protein precipitates. The appearance of such a precipitate in an alkaline filtrate may, of course, be disregarded. Another way to test for completeness of precipitation is to use slightly different amounts of the precipitant. The results tabulated in Table 2 show that the amounts of acetic acid used were sufficient and that slight variations in the strength of the acid made no difference in the results. For the sake of certainty, the 10 per cent acetic acid solutions were titrated against standard alkali before being used as precipitants. This is especially desirable where the first determination is made in one laboratory and the second after cold storage in another.

In a few instances ferric chlorid was used as a precipitant for the purpose of comparing the results with those obtained with acetic acid.

Since evaporation can not be altogether prevented during the long filtration, it is necessary to be certain that equal volumes of filtrates obtained from the same lot of butter before and after storage correspond to exactly equal weights of butter, or, if through any considerable difference in evaporation the two filtrates are unequally concentrated, the difference in concentration must be ascertainable.

After filtration is nearly complete—that is, after obtaining a little over 400 cubic centimeters of filtrate—its specific gravity is determined. A 50 cubic centimeter pycnometer was used. The same pycnometer filled a second time with some of the same filtrate will differ from its first weight by only 1 milligram. A little calculation will show that before the nitrogen content of the filtrate can be appreciably varied through evaporation, the specific gravity will be varied so much more that its detection will be easy and require no fine weighings of the pycnometer. The pycnometer full of filtrate was always quickly dried and weighed, and the weight recorded. The weight of a known volume of the clear filtrate is the best of the control figures, and together with the others should in every case show whether or not two filtrates of supposedly equal concentration really were so. The container in which the butter is stored might leak. There would result, not alone a loss in moisture, but in salt and nitrogen as well. Or if the container did not altogether prevent evaporation of water and a subsequent concentration of salt and nitrogen resulted, the pycnometer weighings will probably indicate the source of variation. When 100 cubic centimeters of curd solution were used, the filtrate contains so much sodium chlorid that considerable variation in specific gravity is possible. The amount of curd solution used corresponded to nearly 700 grams of butter.

After weighing the pycnometer full of the clear filtrate, 400 cubic centimeters of it were transferred to a Kjeldahl flask and total nitrogen was determined in the usual way. The remainder of the filtrate was measured and the total volume of filtrate obtained was recorded. If filtration was very slow, sometimes less than 400 cubic centimeters were used. The results were calculated to 400 cubic centimeters. The weight of the precipitate and inclosed filtrate was ascertained to the nearest gram on a torsion balance, and recorded. The 400 cubic centimeters of filtrate actually kjeldahled and titrated corresponded to 560 grams of butter. Rahn, Brown, and Smith[1] determined nitrogen in butter not precipitated by acetic acid. They washed butter with water in the proportion of 1 gram of butter to 2 cubic centimeters wash water, transferred 100 cubic centimeters of these washings to a flask, added acetic acid, filtered off the precipitated protein, and determined total nitrogen in 25 cubic centimeters of filtrate, which corresponded to not quite 12½ grams of butter. Apparently they obtained very few results with acetic acid and did not use them in drawing their conclusions. It was pointed out before (see p. 10) that when butter curd solution is diluted with sufficient water it may be treated with acetic acid as if it were so much diluted milk and the casein will be flocculated, permitting very satisfactory filtration. The filtrate, however, contains an undesirably small amount of nitrogen.

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[1] Loc. cit., pp. 14-15.

The figure for total nitrogen in the filtrate taken for analysis was multiplied by 5/4, and the result recorded as the number of cubic centimeters of N/5 nitrogen in 100 cubic centimeters butter curd solution. (See Table 2.) From the data it is obvious that the unavoidable errors of ordinary nitrogen determinations are very small when compared with the amount of nitrogen determined.

A separation of the various forms of nitrogen in the filtrate from the casein precipitation could easily have been made. But it was considered desirable first to find out whether this filtrate contained any more nitrogen after storage than before. If it did, indicating that proteolysis was taking place, then a more detailed examination of the filtrate would have been made. But the filtrates differed very little in their total nitrogen content before and after storage, indicating that proteolytic changes were not taking place to any great extent, and other lines of work were begun.

The above-described method for the estimation of water-soluble nitrogen in butter was used in the summer of 1910 and in the spring of 1911. (See Table 2.)

Description of samples.—Samples Nos. 42 and 40 were churned from the same lot of sweet cream, half of which was churned unpasteurized (butter No. 42) and half of which was churned after pasteurization (butter No. 40). Samples 52 and 50, and samples 65 and 62 were likewise obtained from churnings of two lots of sweet cream, part of which was pasteurized, part of which was not, before churning. (See Table 2.) The expectation was that if galactase is active in butter during cold storage, the figures for water-soluble nitrogen in samples 42, 52, and 65 would become larger, for in these samples of butter from unpasteurized cream the conditions for proteolysis were as favorable as they ordinarily can be. No great changes were expected in the water-soluble nitrogen in the controls Nos. 40, 50, and 62 because at the temperature of pasteurization used, 75° C. (167° F.) in a "flash" pasteurizer, the galactase ordinarily present in butter is strongly inactivated or partly destroyed.

Samples 511 and 523 were churned from the same lot of pasteurized cream. Sample No. 511 contained a proteolytic enzym preparation obtained from cultures of acid-forming bacteria which also liquefied gelatin. Twelve grams of dry enzym powder were worked into about 30 pounds of butter with the salt. The control lot of butter No. 523 was made in the same way, except that a similar amount of enzym preparation was added after it was first boiled in water. Similarly, sample No. 466 was churned from pasteurized cream and contained an added proteolytic enzym preparation, while its control, No. 478, contained an equal amount of the enzym that had been boiled before being worked into the butter. The object of studying these samples was to ascertain whether the proteolytic enzym secreted by bacteria often present in cream can digest any of the butter proteins, under storage conditions.

All of the samples in Table 2 were churned in the experimental creamery in Albert Lea, Minn., in the summer of 1910. They were stored a short time in the creamery cooler and then shipped to cold storage at 10° F. (minus 12° C.) in Chicago. Naturally, care was taken to move the material into cold storage as soon after churning as possible. When samples were shipped from Chicago to Washington for analysis, they were removed from the railroad station as soon after their arrival as possible and placed in a refrigerator in the laboratory maintained at a few degrees below 0° C.

At appropriate times samples of the butter were sent to competent judges for scoring. The scores are indicated in their appropriate places in Table 2.

TABLE 2.—*Analytic data and scores—Water-soluble nitrogen*[1] *in sweet-cream butter before and after storage. 10° F. (−12° C.).*

Treatment of cream.	Butter sample No.	N/5 water-soluble nitrogen in 100 c. c. butter curd solution.			Age of sample.	Butter scores.		Volume of butter curd solution used for analysis.	Precipitant, 10 per cent acetic acid.
		Before storage.	After storage.	Difference.		Before storage.	After storage.		
		C. c.	*C. c.*	*C. c.*	*Days.*			*C. c.*	*C. c.*
Unpasteurized	42	32.8	28.9	− 3.9	265	85	85	50	7
		34.0	28.7	− 5.3				50	7
		19.9	14.0	− 5.9				100	(2)
	52	30.3	31.9	1.6	251	87	85	100	10
		28.9	30.3	1.4				100	14
		28.7	29.0	0.3				100	16
	65	26.1	21.2	− 4.9	250	90	....	100	16
		25.1	21.2	− 3.9				100	20
		26.0	21.2	− 4.8				100	22
Pasteurized	40	23.4	24.6	1.2	265	91	90	50	7
		23.4	23.6	0.2				50	7
		13.4	16.0	2.6				100	(2)
	50	19.4	20.7	1.3	251	93	91	100	16
		19.0	19.0	0.0				100	18
		18.7	19.4	0.7				100	20
	62	22.8	17.6	− 5.2	250	92	....	100	16
		22.3	17.6	− 4.7				100	20
		22.7	16.8	− 5.9				100	22
Pasteurized. Dry proteolytic enzym added[3]	511	31.8	26.6	− 5.2	250	92	92	100	18
		32.6	26.5	− 6.1				100	20
		35.1	27.1	− 8.0				100	12
	466	[4] 32.7	72.9	40.2	296	92½	93	(5)	(6)
		[4] 86.1	86.6	0.5				(7)	9
		[4] 117.9	84.1	−33.8				(7)	5
Pateurized. Heated bacterial proteolytic enzym added	523	22.4	23.5	1.1	250	93	93	100	18
		22.8	23.5	0.7				100	20
		23.6	24.4	0.8				100	12
	478	[4] 22.0	....	....	296	93½	93½	(5)	(2)
		[4] 23.9	55.0	31.1				(5)	(3)
		[4] 75.0	68.7	− 6.3				(7)	9
		[4] 112.8	72.3	−40.5				(7)	5

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[1] Calculated total nitrogen in 100 cc butter curd solution equivalent to nearly 700 grams butter—350 cc N/5 nitrogen.

[2] Eight c. c. 10 per cent ferric chlorid solution.

[3] Analytical work, June, 1911, on butter, buttermilk, etc., by R. P. Norton.

[4] N/5 water-soluble nitrogen in 1,000 grams butter.

[5] Equivalent of 800 grams of butter.

[6] Ten c. c. 10 per cent ferric chlorid solution.

[7] Equivalent of 400 grams of butter.

Discussion of results, Table 2.—In general, fresh butter made from unpasteurized cream (No. 42, for example) has a little more water soluble nitrogen than the corresponding sample (No. 40) churned from some of the same lot of cream after pasteurization. Buttermilk from raw-cream butter contains more water-soluble nitrogen than the corresponding sample of buttermilk from pasteurized cream. (Compare samples 13 and 14, Table 3.) In sterilized skim milk the soluble nitrogen content is still lower. (Compare samples 20, 22, and 24 with 14, 16, and 18, Tables 3 and 4.) These differences between pasteurized and unpasteurized samples are very likely due to the partial or entire coagulation of the milk albumin, and its removal from the water-soluble condition.

The coagulation of water-soluble nitrogenous substances in buttermilk due to high pasteurizing temperatures was shown in a previous publication from the Dairy Division laboratories.[1]

It is believed that samples 42, 52, and 65 contained more water-soluble nitrogen than their controls Nos. 40, 50, and 62, because there was a partial precipitation of protein during the pasteurization of the cream from which the latter were made and not because the galactase undoubtedly present in Nos. 42, 52, and 65 was active. If it were, there should have been an increase in the amount of water-soluble nitrogen after storage. In so far as there was none, it is inferred that the activity of the galactase was inhibited by the combined effect of the salt and cold storage.

The differences between the amounts of water-soluble nitrogen in the different samples of butter before and after storage are not very large, except in samples 466 and 478, and they represent in all probability the unavoidable error in such work. It is to be borne in mind that the first analysis was made in Albert Lea, Minn., and the second on a different lot of cans in Washington, D. C. Under such circumstances the differences are not considered large. In samples 466 and 478 it is probable that the figures obtained for nitrogen are erroneous.

CONCLUSIONS.

From the data obtained it is evident that proteolysis did not take place to any appreciable extent in the samples studied. Nor was there any simple or obvious relation between the figures for nitrogen and the butter scores.

As the following calculations show, the method for detecting proteolytic action in butter is quite delicate and should lead to the detection of proteolysis were it appreciable. In a determination of water-soluble nitrogen in butter 100 cubic centimeters of curd solution were used. This is equivalent to a little over 700 grams of butter containing 13 per cent of moisture. A nitrogen determination was made in 400 cubic centimeters of the filtrate from the acetic acid precipitation, equivalent to 560 grams of butter. The butter used contained an average of 0.9 per cent of curd. The 700 grams of butter contained, therefore, $700 \times 0.009 \times 0.1567 = 0.9872$ grams of nitrogen, equivalent to 352 cubic centimeters N/5 nitrogen.

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[1] Rogers, L. A., Berg, W. N., and Davis, Brooke J. Loc. cit., p. 317.

Suppose that during the cold-storage period 5 per cent of the casein was slightly proteolyzed and became water soluble. It should be borne in mind that the method of detecting proteolytic action here described will detect it in its first stages. In this respect the method possesses undoubted advantages over others in which results are obtained for variations in amounts of proteoses, amino acids or ammonia, which correspond to later and later stages in the digestive process. It is here supposed that the first step in the digestion of 5 per cent of the casein has taken place, the rest of the protein remaining unchanged. Allowing for 30 cubic centimeters N/5 nitrogen already present in the 100 cubic centimeters of curd solution as water-soluble nitrogen, there would be formed by the proteolysis 0.05×320 cc $= 16$ cubic centimeters N/5 nitrogen in the water soluble form in addition to the 30 cubic centimeters originally present. The titrations made after storage would then show $16 \times 4/5$ or 12 cubic centimeters more of N/5 nitrogen than before storage. From the results obtained it is probable that this increase, had it taken place, would have been detected.

A protein, such as casein, can of course undergo more than one kind of chemical change. These changes may be hydrolytic, oxidative, or putrefactive. It is obvious that the methods used in this work would detect the hydrolytic change only. Some work on the possibility of oxidative changes in the protein in butter is described on page 64 et seq.

PROTEOLYSIS IN MILK.

POSSIBLE OBJECTION TO THE NEW METHOD FOR DETECTING PROTEOLYSIS IN BUTTER.

An apparent objection to the method of studying possible proteolytic changes in butter just described lies in the fact that a long time (five days) may elapse between the beginning and end of the determinations of nitrogen, during which time the galactase or bacterial proteolytic enzyms present in butter may be active. The results would not represent proteolysis during cold storage but proteolysis during the determinations of nitrogen. For this reason the following experiments were made.

The objects of these were two-fold: First, to ascertain by a method that was free from the objections to the method for butter whether galactase could digest protein in an 18 per cent sodium chlorid solution. Second, whether the sodium chlorid usually present in butter curd solutions can inhibit the proteolytic action, not alone of the small quantity of galactase ordinarily present in butter, but also the action of larger amounts of proteolytic enzyms that might find their way into butter in any one of several ways, as, for instance, the proteolytic bacteria that may grow in the milk and cream.

THE INHIBITING EFFECT OF SODIUM CHLORID AND COLD STORAGE UPON THE ACTIVITY OF GALACTASE IN BUTTERMILK.

Six lots of buttermilk of about eight liters each were obtained from three churnings of unpasteurized sweet cream and from three churnings of pasteurized sweet cream. In Table 3, page 29, is indicated the number of the lot of butter corresponding to each lot of buttermilk. Buttermilk samples 13 and 14 were obtained from the churning of one lot of sweet cream, half of which was churned unpasteurized (butter No. 42, buttermilk No. 13) and half of which was pasteurized before churning (butter No. 40, buttermilk No. 14).

To each liter of buttermilk 5 cubic centimeters of chloroform and 180 grams of sodium chlorid were added. These samples were intended to represent approximately butter minus butterfat. In such material a study of possible proteolytic action could be made in a comparatively short time, since no time is necessary for the melting of the butter or the separation of the fat.

The buttermilk was then sealed in cans, each containing 600 cubic centimeters of the sample. These cans, which were also used for butter, were of heavy tin, thoroughly lacquered. The smaller part of these samples remained in the creamery cooler; the rest were shipped to cold storage in Chicago. The samples were not removed from the cooler for analysis until it was certain that sufficient time had passed to permit the transportation, by refrigerator freight, of the samples from Albert Lea, Minn., to Chicago, and the placing of the samples in the cold-storage rooms. It was intended that the first analysis of these samples should show, as closely as possible, the amount of water-soluble nitrogen present in the material as it went into cold storage, and not as it left the churn. It is highly probable that galactase, even in the presence of 18 per cent sodium chlorid, can slowly digest protein material, if the temperature is above that of cold storage as it is ordinarily practiced. It seems reasonable to suppose that the proteolysis in butter observed by Rahn, Brown, and Smith [1] was due, in part at least, to the comparatively high temperatures at which their butter was stored. But in so far as this investigation is concerned with possible chemical changes that may take place in butter while in cold storage and not at higher temperatures, the times at which analyses were made were always chosen so as to give results as nearly representative of the condition of the material immediately before and after cold storage as possible.

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[1] Loc. cit.

Method of measuring the activity of galactase in buttermilk.—When it was reasonably certain that the other samples of buttermilk had reached the cold storage, samples were removed from the creamery cooler and water-soluble nitrogen was determined in them by practically the same method as was used for butter. The buttermilk was treated as if it were so much butter curd solution entirely freed from fat. All the precautions that were taken in the work on butter were taken here also. The method is described on page 18.

The first analyses were made in September and October, 1910. For the analyses made in December, 1910, and in June, 1911, samples were shipped from cold storage in Chicago by express to Washington. Upon their arrival the material was at once transferred to the refrigerator in the Dairy Division laboratories, where it remained till used for analysis. The total time during which the samples were out of cold storage was as short as possible.

Results.—From the results obtained on samples 13, 15, and 17, summarized in Table 3, it is evident that in buttermilk obtained from raw-cream butter the activity of galactase is practically entirely inhibited by the presence of 18 per cent of sodium chlorid and by the low temperature, 0° F. (−18° C.) of the cold storage. When some of this same material is allowed to remain for a long time at room temperature, the galactase apparently becomes much more active, because the casein is seen to clot and the mixture assumes the appearance of one in which digestion is going on.

Samples 14, 16, and 18 were to serve as controls on those of the other three. Although galactase in cream is not entirely destroyed by ordinary pasteurization, it is partly inactivated.[1] It was expected that the figures for water-soluble nitrogen in samples 14, 16, and 18 would change little during storage, thereby affording a check on the correctness of the work. The figures for water-soluble nitrogen in samples 13, 15, and 17, had they increased during storage, could then have been considered as obtained by a method that showed no change where none is to be expected.

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[1] Rogers, L. A., Berg, W. N., and Davis, Brooke J. Loc. cit., p. 318.

TABLE 3.—*Effect of sodium chlorid and cold storage (0° F., −18° C.) upon the activity of galactase in buttermilk.*

Buttermilk obtained from churnings of unpasteurized sweet-cream butter.					Buttermilk obtained from churnings of pasteurized sweet-cream butter.				
Buttermilk, lot No. 16.612, sample No.	Butter, lot No. 10.311, sample No.	N/5 water-soluble nitrogen in 100 c. c. buttermilk.		10 per cent acetic acid used as precipitant for 200 c. c. buttermilk.	Buttermilk, lot No. 10.622, sample No.	Butter, lot No. 10.321, sample No.	N/5 water-soluble nitrogen in 100 c. c. buttermilk.		10 per cent acetic acid used as precipitant for 200 c. c. buttermilk.
		Age.	N/5 N.				Age.	N/5 N.	
		Days.	*C.c.*	*C.c.*			*Days.*	*C.c.*	*C.c.*
13	42	25	39.2	20	14	40	25	36.1	18
			36.8	18				38.2	12
		116	40.7	20			116	39.1	12
			41.0	18			301	36.3	18
		301	37.2	20				38.3	12
			37.4	18	16	50	10	31.1	20
15	52	10	42.1	16				30.3	24
			40.9	20			124	31.9	20
		124	43.4	16				30.3	24
			42.6	20			297	30.1	20
		297	39.5	16				28.6	24
			40.0	20	18	62	10	35.0	22
17	65	10	42.6	14				36.3	18
			45.3	12			101	35.2	22
		101	45.1	14				36.3	18
			46.3	12			286	33.6	22
		286	41.1	14				34.8	18
			38.7	12					

179 cubic centimeters N/5 nitrogen=average total nitrogen in 100 cubic centimeters buttermilk.

The results on these samples of buttermilk confirm the results obtained on the corresponding samples of butter. It is practically certain, for example, that butter sample No. 42 and the buttermilk obtained from it both contained galactase, though in different amounts. Under the conditions of the experiments proteolytic action was uniformly inhibited, both in the butter and in the buttermilk.

As the following calculations show, the method used for the detection of proteolytic action in buttermilk (skim milk) is quite delicate and should lead to the detection of proteolytic action were it appreciable. In the determination of water-soluble nitrogen in buttermilk 200 cubic centimeters were taken, which contained very close to 360 cubic centimeters N/5 total nitrogen. Let it be assumed that during the cold storage period 5 per cent of the casein became water soluble. Allowing an average of 80 cubic centimeters N/5 nitrogen in water-soluble form originally present in the 200 cubic centimeters of buttermilk, there would be formed by the proteolysis $0.05 \times 280 = 14$ cubic centimeters N/5 water-soluble nitrogen. In the actual determination 200 cubic centimeters of buttermilk were diluted to 500 cubic centi meters precipitated with acetic acid, and two 200 cubic centimeter portions of the filtrate were used for nitrogen determinations. Therefore if 5 per cent of the casein had become hydrolized the titrations after cold storage would have been 5.6 cubic centimeters higher than the corresponding titrations before storage. It is probable that this increase would have been detected.

THE INHIBITING EFFECT OF SODIUM CHLORID AND COLD STORAGE UPON THE ACTIVITIES OF PROTEOLYTIC ENZYMS IN STERILIZED SKIM MILK.

Description of samples.—Several 5-liter flasks full of skim milk were kept in a steam sterilizer for about two hours at a temperature varying between 94° and 99° C.

Three 3-liter portions were measured out roughly and rapidly while the skim milk was hot, into bottles, samples No. 20, 22, and 24. A weighed quantity of the enzym preparation was then added. The amounts are given in Table 4, page 30.

After cooling, 540 grams of sodium chlorid was added to each sample. The bacterial enzym was prepared from cultures of an acid-forming bacterium that secreted a proteolytic enzym. The usual method of precipitating with alcohol, etc., was used. The dry enzym preparation was tested before it was used in the experiments and found to be proteolytically active. The other enzym preparations were the ordinary commercial ones.

Three-liter portions of the skim milk were quickly cooled to 35° C. To each was added 540 grams of sodium chlorid, to which there had been previously added the amount of enzym indicated in the table. Obviously, samples 20, 22, and 24 were controls on Nos. 19, 21, and 23.

These samples were canned as before. Most of these were shipped to cold storage in Chicago, where they were maintained at a temperature of 20° F. (– 7° C.). Determinations of water-soluble nitrogen were made by the method already described in a previous publication[1] and in this paper page 18.

TABLE 4.—*Effect of sodium chlorid and cold storage upon the activities of proteolytic enzymes in sterilized skim milk stored at 20° F. (–7° C.).*

Skim milk, lot No. 10.612, sample No.	Composition of mixtures.	N/5 water-soluble nitrogen[2] in 100 c.c. skim milk after 75 days' storage.	10 per cent acetic acid used as precipitant for 200 c.c. skim milk.	Skim milk, lot No. 10.622, sample No.	Composition of control mixtures.	N/5 water-soluble nitrogen[2] in 100 c.c. skim milk after 77 days' storage.	10 per cent acetic acid used as precipitant for 200 c.c. skim milk.
		C. c.	*C. c.*			*C. c.*	*C. c.*
19	Skim milk, 3 liters	44.9	20	20	Skim milk, 3 liters	28.1	20
	Dairy salt, 540 grams.	48.1	10		Dairy salt, 540 grams.	33.1	10
	Bacterial........	....	....		Bacterial........	....	....
	Enzym (dry), 15 grams.	....	....		Enzym (boiled), 15 grams.	....	....
21	Skim milk, 3 liters	118.2	20	22	Skim milk, 3 liters	22.8	20
	Dairy salt, 540 grams.	121.0	10		Dairy salt, 540 grams.	28.5	10
	Pancreatin, 3 grams, dry (U. S. P.).	....	....		Pancreatin (U. S. P.), boiled, 3 grams.	....	....
23	Skim milk, 3 liters	54.1	20	24	Skim milk, 3 liters	19.8	20
	Dairy salt, 540 grams.	65.5	10		Dairy salt, 540 grams.	24.2	10
	Pepsin (U. S. P.), dry, 3 grams.	....	....		Pepsin (U. S. P.), boiled, 3 grams.	....	....

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[1] Rogers, L. A., Berg, W. N., and Davis, Brooke J. Loc. cit., p. 315.

[2] 198 c. c. N/5 nitrogen = average total nitrogen in 100 c. c. skim milk.

Results.—In sample No. 19 there was present a large quantity of a proteolytic enzym of bacterial origin that was known to be active on gelatin. It is highly probable that much more enzym was present here than there is ever present in butter, and the figures indicate plainly that the salt strongly inhibited its action during the period under observation. It is, of course, possible that, given a period of time greatly exceeding ordinary storage periods, further proteolysis in this sample might have been observed.

In samples 21 and 23 digestion took place to a large extent. In No. 21 approximately two-thirds of the total protein had become water soluble.

On samples 20, 22, and 24 practically identical results were obtained before and after storage, as would be expected. This indicated that in the controls no proteolytic changes were detected.

CONCLUSIONS.

It is evident from these results that in the presence of very large amounts of strongly active proteolytic enzyms, proteins will be hydrolized even in cold storage (or in transit) and in strong salt solutions. But there is no reason to suppose that at any time such amounts of enzyms are ever found in butter.

It is very probable that samples 21 and 23 contained several thousand times as much proteolytic enzym as is present in ordinary butter of any kind.

However, it must be borne in mind that the claim is not made that sodium chlorid does not exert an inhibiting influence on proteolytic action. Whether it does or does not depends upon the conditions of the experiment. It is comparatively easy to show that the action of pepsin-acid can be inhibited very strongly by large amounts of sodium chlorid. In the spring of 1909 some experiments were made in which the speed of digestion of casein in several pepsin-acid solutions was compared with that in the same solutions to which 20 grams of sodium chlorid to 100 cubic centimeters of acid solution had been added. The presence of the salt almost completely inhibited the action of the pepsin-acid during the time of the experiment, 40 minutes' digestion, but it is, of course, possible that proteolytic action would have taken place had the digestion period been several months. The method of comparing speeds of digestion was that described by Gies.[1] In general, the statement that sodium chlorid does inhibit proteolysis is true, therefore, at low temperatures, when the amount of enzym is small and the digestion period (storage period) is long or when the amount of enzym is large and the digestion period is short, as in ordinary digestion experiments.

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[1] Berg, William N., and Gies, William J. Studies of the effects of ions on catalysis, with particular reference to peptolysis and tryptolysis. Journal of Biological Chemistry, vol. 2, no. 6, pp. 489-546. New York, March, 1907.

The statement that sodium chlorid does not inhibit proteolytic action is true at comparatively high temperatures when the amount of enzym is very large and the digestion period very long. The apparently contradictory statements are the results of testing the action of the sodium chlorid over a wide range of enzym concentration and over widely varying digestion periods.

Several investigators have studied the action of sodium chlorid on the tryptic digestion of casein. Their conflicting statements are, of course, easily accounted for by the fact that the experiments were made under conditions that were not uniform with regard to the concentration of sodium chlorid, the relative proportions of alkali, trypsin, and casein, etc. Their work is summarized by Robertson.[1]

THE INDIRECT ACTION OF BACTERIA.

The improbability that the proteolytic enzyms are responsible for the difference in keeping quality between unpasteurized and pasteurized sweet-cream butter is shown by the work given in detail in the preceding pages. The bacteria are another possible factor removed by pasteurization. While it is certain that they do not grow at the low temperature of commercial storage, it is possible that the presence of a large number of living cells, or various active enzyms which may possibly be liberated by the death of the bacteria, may have an influence on the flavor of the butter. If the bacteria destroyed by the pasteurization could be replaced in the cream their influence on the flavor should be shown in a comparison of the butter made from this reinoculated cream and that made from a part of the same pasteurized cream, but without the addition of bacteria. Before this could be done intelligently it was necessary to obtain a general knowledge of the bacteriological content of the raw cream. The normal bacteria of the cream from one skimming station was determined by sampling every day and plating on lactose agar. After 7 days' incubation at about 30° C. the plates were counted and all of the colonies on a representative plate were transferred to litmus milk tubes. These were incubated and examined after 2, 5, and 14 days. This enabled a separation into high acid forms which curdled the milk in less than 2 days; low acid forms forming acid but curdling the milk slowly or not at all; alkali formers, peptonizers, and those that produce no visible change in the milk. These groups were calculated as percentages of the total bacteria, and the results are given in Table 5.

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[1] Robertson, T. Brailsford. On some chemical properties of casein and their possible relation to the chemical behavior of other protein bodies, with especial reference to hydrolysis of casein by trypsin. Journal of Biological Chemistry, vol. 2, no. 4, pp. 317-383. New York, January, 1907. See p. 355.

TABLE 5.—*Numbers of bacteria with distribution in different groups in cream.*

No.	Bacteria per cubic centimeter.	High acid.	Low acid.	Alkali.	Peptonizers.	No change.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
1	116,000,000	25.8	11.3	1.0	1.0	60.8
2	61,000,000	41.6	16.6	6.7	10.0	25.0
3	23,500,000	21.2	7.7	1.0	7.3	62.1
4	40,000,000	48.8	2.4	....	12.2	36.6
5	99,000,000	14.1	9.9	1.1	25.3	50.5
6	34,000,000	36.1	8.4	....	....	55.6
7	11,800,000	16.3	12.1	1.7	12.9	55.9
8	33,500,000	49.0	23.0	....	3.0	25.7
9	51,000,000	27.1	14.6	....	4.2	54.2
10	40,000,000	9.3	2.3	....	7.2	80.0
11	8,000,000	27.9	8.9	6.3	1.3	55.7
12	21,800,000	20.4	3.3	....	6.4	70.3
13	37,000,000	27.8	....	2.8	8.3	61.1
14	101,000,000	68.7	3.6	4.4	4.4	18.7
15	147,000,000	60.2	8.0	5.3	1.8	24.7
16	54,500,000	36.0	6.0	6.0	6.0	46.0
17	69,500,000	29.5	11.5	8.2	3.2	47.5
18	30,000,000	51.7	17.2	3.4	3.4	24.1
19	89,000,000	42.9	7.7	2.2	1.1	46.2
20	98,000,000	15.3	....	....	....	84.7
21	110,000,000	15.0	7.0	....	....	78.0
22	45,000,000	12.6	18.9	....	....	68.5
23	52,000,000	30.0	12.0	....	12.0	46.0
24	87,500,000	6.8	5.7	....	....	87.5
25	39,500,000	7.5	7.5	....	5.0	80.0
26	5,700,000	33.3	1.8	....	....	64.9

It will be noticed that the number of bacteria in the cream was high and that there was great variation in the proportion of the groups from day to day.

REINOCULATION OF CREAM.

Typical cultures were saved from each group and used to inoculate one-half of a lot of pasteurized cream. Sufficient amounts of milk cultures were added to the pasteurized cream to bring the bacterial count at the end of about 24 hours to numbers and proportions approximately those of the cream before pasteurization. This was of course very difficult to control, but the results given in Table 2 show that this was attained within reasonable limits. Two experiments of this kind were made, each consisting of three lots of butter. One-third of a lot of sweet cream was cooled and churned; two-thirds was pasteurized by holding at 145° F. for 20 minutes; one-half of the pasteurized cream was cooled and churned, and the remaining portion inoculated with the milk cultures and held about 24 hours to allow bacteria to develop. There was no appreciable increase in acidity in this period. The cream was then cooled and churned as before. It is probable that the lipase was destroyed and the galactase weakened. Tests showed that catalase was present in the raw cream, absent in the pasteurized cream, and present again in the inoculated cream, while all three lots gave a test for peroxidase.

The score of the butter given in Table 7 shows that while there was a marked difference in the rate of deterioration in the raw-cream butter and the pasteurized-cream butter, the reinoculation of the cream with bacteria had little or no effect on the keeping quality of the butter. In one case the inoculated-cream butter changed more than the uninoculated, while in the other lot the reverse was true.

TABLE 6.—*Bacteria in cream used for making butter.*

Treatment of cream.	Bacteria per cubic centimeter.	High acid.	Low acid.	Alkali.	Peptonizers.	No change.
No. 1.						
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Raw	48,000,000	13.1	10.9	0.0	17.4	58.6
Pasteurized	53,000					
Pasteurized reinoculated	20,000,000	18.7	6.6	0.0	2.5	72.2
No. 2.						
Raw	47,000,000	46.0	6.3	0.0	6.3	41.4
Pasteurized	23,400					
Pasteurized reinoculated	217,000,000	26.8	.5	1.0	1.0	70.7

TABLE 7.—*Scores of butter—raw, pasteurized, and reinoculated cream.*

Treatment of cream.	First score.			Second score.		
	Age, days.	Total score.	Comments.	Age, days.	Total score.	Comments.
Raw	6	86	Very unclean, somewhat rancid.	38	82	Rank, woody, rancid.
Pasteurized	6	92	Slightly woody	38	87	Very woody.
Pasteurized and inoculated.	6	91	Woody	38	91	Somewhat woody.
Raw	4	86	Unclean, rancid	36	82	Rancid, woody.
Pasteurized	4	92	Slightly woody	36	90	Slightly unclean, woody.
Pasteurized and inocuated.	4	91	Woody	36	89	Woody.

It is perhaps significant that raw, sweet-cream butter always becomes rancid, a flavor usually associated with the liberation of fatty acid. It is not improbable that the lipase of the milk is able to act under these conditions, but that the ripening of raw cream, which usually prevents the development of this flavor, inhibits the action of this enzym.

THE POSSIBLE OXIDATION OF BUTTER BY INCLOSED AIR.

The possible oxidation of butter by finely divided air globules inclosed in it, as previously pointed out, made it desirable to find out how much air was present in butter exclusive of large pockets, and second, whether the air present in butter underwent a change during storage through the transfer of oxygen from the air to some oxidizable substance in the butter. The work was done in the field laboratory of the Dairy Division, Troy, Pa.

Method of gas analysis.—The following diagram shows the apparatus used for obtaining the gas from a can of butter. The determination of the amount of air (or gas) in a can of butter was made as follows: The can of butter was removed from the refrigerator late in the afternoon and allowed to remain at room temperature over night. The next morning the can was placed in water at 45° C. for about an hour until the contents of the can were melted. The flasks, previously connected, and the Toepler pump,[1] were then evacuated by the Geryk pump through the tube *d*. Tube *f* could be evacuated by opening the stopcock toward the Toepler pump. The Geryk pump was worked until the McLeod gauge on the Toepler pump read about 0.3 millimeter. The flask *i* and tube *j* were then evacuated. The can punch was then brought under tube *g* and the can of butter placed inside of *n*. The brass plate *q*, carrying the upper needle, was placed over the can. The plate is held over the can by two brass guide rods, threaded at their upper ends and screwed into *r*, the brass base. *q* was then screwed down a short distance, so that the upper end of the upper needle *l* could be brought under the lower end of tube *g*. *l* and *g* were connected by the usual rubber tube and rubber nipple mercury seal. Water at 60° C. was poured into the container until the can was completely submerged. The water was then colored by adding a few cubic centimeters of alcoholic solution of methylene blue. Previous to putting the can of butter into *n*, the funnel *p* was filled with a three-fourths saturated sodium chlorid solution at 50° C. and air bubbles removed from *o*, partly by squeezing *o* and forcing the air bubbles up to *p*,

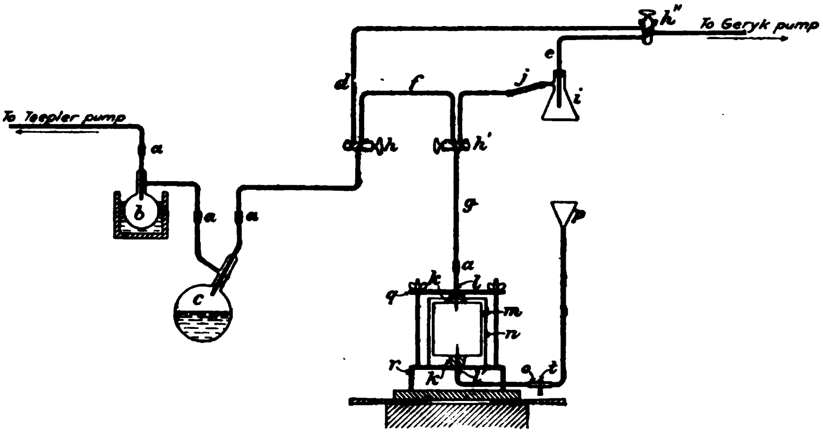

FIG. 1.—Apparatus used for obtaining gas from a can of butter.

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[1] We used an improved form of Toepler pump designed by Dr. Clark, of this laboratory.

and then by opening the screw clamp at *t* and allowing the solution to flow through *l′* into *n*. The two needles were forced into the can by screwing down *q*. In order not to open the mercury seal at the upper end of *l*, the entire punch was raised as fast as *l* was lowered, by means of several thin wooden strips and a wedge on both sides. When it was apparent that the rubber stoppers *k* were pressing very tightly against the can, and very soon the needles would punch the can, *l* and *g* were evacuated by opening the stopcock toward *i*. The entire system was now empty, from *l* to *g*, *f*, *c*, *b*, and the Toepler pump. The Geryk pump was then cut off altogether from the rest of the system. *q* was still further forced down until the lower and then the upper needles pierced the can. When the upper cover was pierced, butter fat would fill tube *g* to stopcock *h′*. This was then opened and butter fat was slowly passed through *f* into *c*, where it remained. The inclosed gases passed on through *b* to the Toepler pump. The screw clamp *t* was removed soon after the butter began to flow out of the can, permitting salt solution to enter the can as fast as butter left it. During the passage of butter fat, and later of butter curd solution, the entire can was covered with water. In only one experiment did any colored solution find its way into the tube *g*. Stopcock *h′* shut off the connection between *g* and *f* when salt solution began to come through *g*. This usually happened when most of the butter fat and part of the curd solution had passed into *c*. Knowing the weight of the can of butter, the empty can, the weight of *c* empty and when filled with butter from the can, the amount of butter passed into *c* could be ascertained approximately. In general between seven and eight tenths of the contents of the can were passed into *c* during the experiment. The gas in the Toepler pump and flasks was then pumped out in the usual way and measured. Part of it, 50 to 60 cubic centimeters, was used for the determination of carbon dioxid and of oxygen. The usual apparatus was used. The determinations were made according to the methods described in Hempel's Methods of Gas Analysis, 1906, pages 149 and 201.

One blank on air was made before the results were obtained, one after, and two between results, so that the reagents were certainly in good condition.

In the third determination on 2A a few drops of colored water were seen to pass up the tube *g*. No more butter (butter fat) was allowed to pass into *c* and the estimation of the quantity and composition of the gas was made as usual. It is probable that the apparently high carbon dioxid was due to greater volatilization of acid-reacting material. In this experiment flask *c* contained 525 grams of butter instead of the usual 700–800 grams.

Results.—The butter used had been churned from pasteurized ripened cream, packed carefully in 2-pound tin cans, and sealed by a sealing machine. Determinations were made before and after storage. Part of the butter was worked normally in the churn (samples marked "A"), part was overworked (samples marked "B"). Samples 1A and 1B were obtained from the same lot of butter and samples 2A and 2B were from another lot.

TABLE 8.—*Quantity and composition of gas in pasteurized ripened-cream butter.*

BEFORE STORAGE.

Lot No. 19.4.	Volume of gas obtained from 1 can (capacity approximately 1 liter) of butter reduced to 0° C. and 760 mm. of mercury.	Composition of gas.	
		Carbon dioxid.	Oxygen.
Sample No.—	. c.	*Per cent.*	*Per cent.*
1A (normal)	99.6		
1B (overworked)	101.4		
1A	107.7	31.3	19.1
1B	98.8	29.7	20.3
2A	141.5	36.8	19.1
2B	104.6	37.8	19.5
2B	101.4	37.8	18.6
Blank on air		.8	21.87

AFTER STORAGE.

Sample No.—			
1A	94.1	34.2	13.3
1B	76.9	32.5	11.0
2A	139.0	31.5	13.1
2A	112.0	39.3	12.1
2A	71.0	52.8	10.0
2B	117.5	33.6	13.3
Blanks on air		.38	22.1
		.39	21.5
		.39	20.77
		.66	21.82

The results (see table 8) before storage were obtained in November and December, 1911. All of the results for carbon dioxid were obtained on the same pipetteful of potassium hydroxid solution and all of those for oxygen on the same pipetteful of sodium pyrogallate. The blank was made after all the other results had been obtained. Two separate determinations on two cans of 2B showed that the same result could be obtained on two cans of the same lot of butter.

On the assumption that the gas in butter is a mixture of carbon dioxid and air, the oxygen content found is apparently high.

If the percentage of carbon dioxid be subtracted from 100, leaving, for example, 70 per cent of the gas supposedly air, the percentage of oxygen (20) forms too large a part of the total volume of gas from which carbon dioxid has been removed.

The butter was stored at 0° F. until the following March, 1912, during which month the results after storage were obtained.

The results are difficult to interpret, partly because very few of them have as yet been obtained and partly because certain check experiments not yet made will be necessary. There seems to be n great variation in carbon dioxid content, but a decided lowering of the oxygen content as if part of this gas had been removed. It is possible that further work will show that the oxygen in these experiments was actually transferred to some oxidizable substance in the butter. It would perhaps be better to defer conclusions until further work shows that the oxygen, if it was indeed removed, went to some butter constituent and was not combined with metal or diffused out through the seals. It seems highly desirable to ascertain definitely whether cans sealed by a machine without the use of solder are gas tight, measuring gas tightness for a period of several months.

The cans used were heavily tinned and well lacquered on the inside. The rims of the covers were provided with a layer of rubber cement, which was forced into the seal by the sealing machine. Cans sealed in this way are air tight when tested under 15 pounds' pressure for a short time.

The figures for the composition of the gases in butter obtained after storage show that the gas is apparently a mixture of carbon dioxid and air. At present any conclusion regarding the nature of the gas is premature. It seems almost certain that the gas in these samples was not a mixture of carbon dioxid and air only, but that some volatile substance was mixed with it. The gas obtained from butter had an intensely "buttery" odor. Perhaps a more detailed analysis of the gas will make the results more intelligible. Under the circumstances it is not safe to assume that the figures for carbon dioxid represent carbon dioxid alone, for any substance having an acid character and volatile under the conditions of the experiment would probably be included with the carbon dioxid in the potassium hydroxid. absorption. These results show that butter contains about 10 per cent by volume of gases.

Overworked butter did not contain any more air than that which had been normally worked. For obvious reasons these results are not comparable with those obtained by overworking small amounts of butter with a spatula.[1] It may, however, be significant that the decrease in oxygen as shown in Table 8 was about 50 per cent greater in the overworked sample, 1B, than in any other.

THE EFFECT OF METALS ON BUTTER.

EARLIER INVESTIGATIONS.

The influence of metals on the changes in butter has received some attention, although most of the experiments along this line have not included storage butters. In 1902 Henzold[2] found butter with a bitter astringent taste, which he concluded was caused by iron in the salt. He made butter from pasteurized cream, to which salt containing 0.05 to 0.1 per cent iron oxid was added. The butter made, using this salt, had a decidedly bitter taste. By elimination and control of conditions, the iron was found to be the factor influencing this taste.

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[1] Rogers, L. A. Fishy flavor in butter. United States Department of Agriculture, Bureau of Animal Industry, Circular 146. Washington, 1909.

[2] Henzold, Ottomar. Bittere Butter. Milch-Zeitung, vol. 31, no. 52, pp. 822–823, Leipzig, Dec. 27, 1902.

L. Marcas [1] showed the effect of holding milk and cream in rusted cans for from 2 to 46 hours and making butter from the cream treated in this manner. He determined the amount of iron in the milk, skim milk, cream, butter, and buttermilk, holding part in a clean can and the other in a rusted can for comparison. He found in all cases a bitter, astringent taste and bad odor in butter made from milk held in rusted cans, while the butter made from the milk held in clean cans was of good quality. He concluded that the milk coming in contact with the iron rust forms iron lactate from the iron oxid and that it is the lactate which causes the bitter taste. This solvent action he found to be especially active in cream, owing to its acidity. He found that cream with a normal iron content of 0.005 parts per 1,000 would increase to 0.240 by 22 hours' contact with a rusted can and to 0.270 by 46 hours' contact. Butter made from the cream containing 0.240 parts per 1,000 contained 0.080 parts of iron per 1,000, while butter made from cream containing 0.270 parts per 1,000, contained 0.134 parts of iron per 1,000.

Höft [2] in 1909 added iron salts (ferrous ammonium sulphate and iron lactate) to cream, allowed the cream to stand up to 22 hours, made butter, scored it for physical changes, and made qualitative tests for iron in the butter. He added iron in quantities ranging from 2 parts per 1,000,000 to 33 parts per 1,000,000. He published results of only eight tests, which showed in most cases an oily metallic taste in the butter and in which the presence of iron in the curd solution was determined with potassium sulphocyanid. He, however, cautioned against definite conclusions, as he had not decided that the change was due to iron unconditionally. He found that small amounts of iron acting for a long time caused more effect than large quantities of iron for a short time.

In 1911 the Molkerei-Zeitung [3] published some work on the effect on butter of washing it with water containing 9 to 15 milligrams iron per liter. This caused the butter to have a metallic, oily, tallowy taste. The butter when washed with water from which the iron had been removed by oxidation and filtration did not show the faults mentioned. It was also found that holding cream in rusted vessels caused this oily, metallic taste.

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[1] Marcas, L., and Huyge, C. Influence de la rouille sur la qualité du beurre. L'Industrie Laitière, vol. 30, no. 16, pp. 187-188. Paris, Apr. 16, 1905.

[2] Höft, Dr. Kann man aus dem chemischen Nachweis von Eisen in der Butter auf eine Qualitätsverminderung der Butter durch das Eisen schliessen? Milchwirtschaftliches Centralblatt, vol. 5, no. 6, pp 250-252. Leipzig, June, 1909.

[3] Enteisenungsanlage für Molkereiwasser. Molkerei-Zeitung, vol. 25, no. 58, pp. 1095-1096. Hildesheim, July 28, 1911.

Kooper,[1] in 1911 did some work to show that washing butter with water containing pure metallic iron would not, in quantities up to 36 milligrams per liter, cause any noticeable changes in the quality of the butter, but that the changes that took place were caused by other substances in the water together with the iron. He is of the opinion that water containing a high percentage of iron is very likely to contain H_2S or nitrous acid, which would be more likely to cause the changes and defects in the butter than the iron itself. Kooper used a saccharated iron carbonate in his work. He says, however, that a change of the iron to lactate is caused by contact of high acid cream with iron, and this will produce the oily and metallic flavors. According to Kooper the iron taken up depends on the length of time of contact and the acidity of the cream. By adding rusted nails or pulverized iron rust to the cream before ripening and allowing the cream to ripen in contact with the iron rust he found the cream to be changed to a grayish color and showing defects in odor and taste. He also showed that the washing tended to take some of the iron from the butter.

A summary of the preceding work, then, shows that some investigators think the iron in wash water (9 to 15 milligrams per liter) is responsible for the changes in butter, while others do not think the iron alone (up to 36 milligrams per liter) will cause the changes. All seem to agree that the contact of acid cream will take up iron from rusted containers, change it to a lactate, and produce butter of poor flavor.

In order to see whether butter containing iron would change more in storage than clean butter, it became necessary to make butter which contained no impurity or foreign matter other than iron and also to make a control butter containing no foreign material and free from iron.

Anyone familiar with creamery methods will readily see that to make butter free from contact with iron would require careful supervision of the cream from the time of milking to the making of the butter. In order to do this, the cream was all selected from farmers who were careful in the handling of the cream and whose cans were free from rust, as this is the first opportunity for contact with iron. The cream was, in most cases, pasteurized in a Jensen flash pasteurizer at 75° C. This was carefully cleaned. The cream was cooled, weighed, and then ripened in enamel-lined tanks free from iron. These tanks were made especially for this work to eliminate any chance for contact with iron during ripening, at which time, owing to the acidity of the cream, the cream would be most likely to attack and dissolve the iron. A pure culture starter was used, the same precautions in regard to metals being taken in the preparation of the starter. After pasteurizing, the cream was divided into two portions, each being put into an enamel-lined tank for ripening. The cream was cooled by running brine through tinned copper coils so suspended in the vats that they could also be used for stirring and mixing. The cream in one vat was held under normal conditions and free from iron. To the cream in the second vat there were added known amounts of iron. Both ferrous sulfate and ferrous lactate were used in this work. This iron was added in amounts varying from 1 to 500 parts of iron per million of cream (or 1 to 500 milligrams of iron in a kilo of cream). The two vats of cream were then ripened under like conditions and churned at the same time in the Disbrow combined churns and workers (B2, of 50 gallons capacity). These churns were shipped to Troy, Pa., from Albert Lea, Minn., in the spring of 1911 and were exposed for some time. Before using at Troy they were taken apart, scraped, sandpapered, and thoroughly cleaned, though in spite of this one iron plate at the side showed rust which was exposed to the cream. The butters were worked the same amount, salted the same, and washed with the same amount of water and the same number of revolutions in wash water. This was considered an essential point, as Kooper found that butter that was washed and worked held less iron than that which was worked without washing. The butters were then carefully packed in glass jars, with glass tops, to avoid any contact with metals, and placed in storage. The butters made at Albert Lea, Minn., were scored about a week after making and again after three months' storage at 10° F. This butter was scored by J. B. Neumann, J. C. Joslin, P. H. Keiffer, and the Fox River Butter Co., none of whom were familiar with the history of the butter. As these butters were shipped to several cities, it was impossible to get scores on the day the butters were made, the time usually approximating one week.

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[1] Kooper, W. D. Ist der Eisengehalt des Wassers von Einfluss auf die Qualität der Butter? Milch-Zeitung, vol. 40, no. 29, pp. 285-287. Leipzig, July 22, 1911.

The butter made at Troy, Pa., was scored by Mr. Fryhofer and Mr. Smarzo, of New York City, after from two to four days, again after about a month, and again after about three months' storage at from 6° to 10° F. By comparison of the scores of the control butters and those to which iron had been added at the different intervals the effect of the iron on the quality of the butter was determined by the score for flavor, aroma, and body.

In order to determine the relation between the amount of iron present in the butter and the deterioration of the butter, it became necessary to know the amount of iron present, as well as the changes shown by the scores.

The very small amount of iron present in normal butter (averaging 1.33 milligrams per kilo for 10 samples from Troy Creamery Co.) necessitated the use of a very delicate method. The colorimetric method for iron with potassium sulphocyanid is, according to Neumann,[1] so delicate as to show 1 part of iron in 1,600,000 parts of water. This method was employed for the determination of the iron.

METHOD OF ANALYSIS.

The method of analysis used is as follows: About 500 grams of butter are melted and the clear supernatant fat separated from the curd solution. At first the fat was disregarded and only the curd solution used for analysis. Later the fat, too, was analyzed and found to take up approximately 10 per cent of the total iron in the butter, so that in all later work the fat and curd were both analyzed for iron content. The curd solution is evaporated almost to dryness, the remaining fat burned off, and then ashed at a low heat. The fat, by heating to its ignition point, will ignite and burn; the residue containing some small pieces of curd which remained in the fat is ashed. This ash, when total iron is wanted, is added to the ashed curd and the whole extracted with hot dilute hydrochloric acid and filtered into a graduated 300 cubic centimeter flask. It may be necessary to extract several times, and perhaps even burn the filter and residue and again extract in order to be sure to get out all the iron. In order to avoid any contamination with iron, this process of ashing is carried out in platinum dishes and a platinum spatula used in stirring or scraping the ash from the dish. These separate extracts and washings are all filtered into the same volumetric flask and diluted to 300 cubic centimeters with iron-free distilled water. This solution is then oxidized to have all iron in the ferric condition and an aliquot portion (from 0.5 to 10 cubic centimeters, depending on the iron present in the solution) transferred to a 50 cubic centimeter Nessler tube. Then 5 cubic centimeters of a 10 per cent solution of potassium sulphocyanid are added and the whole diluted to 50 cubic centimeters with distilled water. These samples are then compared with a set of standards made by using known amounts of a solution containing 0.0001 gram iron per cubic centimeter and made up to 50 cubic centimeters in the same way as the unknown. These standards fade on standing, so they should be compared shortly after the standards and unknowns are made. The results are calculated to parts per million (milligrams per kilo).

By such an analysis the actual amount of iron in the butter samples is determined. In most cases the iron was added to the cream, and although the conditions were kept as nearly alike as possible, still a difference in the consistency of the butter when washed, or the thoroughness and length of the draining and washing would make a difference in the amount of iron retained in the butter.

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[1] Neumann, B. Die Grenzen der Empfindlichkeit verschiedener Reactionen auf Metalle. Chemiker-Zeitung, vol. 20, no. 79, pp. 763–764. Cothen, Sept. 30, 1896.

Notwithstanding the fact that care was taken to get the best possible cream, the iron content can not be expected to be so low as in cases where the milk is drawn into glass vessels and that portion used for analysis. The normal creams for about 34 samples had an average iron content of 1.53 milligrams per kilo, with a maximum of 3.8 and a minimum of 0.45. Only 6 samples showed over 2 milligrams per kilo. These samples were taken, some at Albert Lea, Minn., some at Troy, Pa., and some at Washington, D. C.

Relation of iron in butter to iron in the cream.—Kooper,[1] in his investigations found that by washing and working butter it would lose some of its iron content. In this work, although care was taken to add the same relative amount of wash water and to work and wash the butter with the same number of revolutions, the iron found in the butter did not show any definite relation to the amount of iron added to the cream. In the first series of experiments analyses were made of the cream, butter, buttermilk, and wash water in an effort to determine whether there was any definite relation between the amount of metal added to the cream and that found in the butter, buttermilk, and wash water, but, as will be seen by the following table, there was no uniformity in the results. The analyses were made on samples of about 500 grams and calculated to milligrams per kilo. The total amount of butter, buttermilk, and wash water were not weighed accurately, and so the total weights of iron in the table are only approximated. In the following results the total approximated milligrams of iron in butter, buttermilk, and wash water have been shown, as well as the percentage return of iron in each of these. A percentage comparison, however, unless based on the same amount of cream (of same fat content), butter, buttermilk, and wash water, and to the cream of which the same amount of iron has been added in each case, really does not enable us to draw any definite conclusions. If the amount of iron added were small, a small variation in the amount returned would make a very much larger percentage difference than if the same variation were shown on a larger addition of iron. This would be especially marked on controls, the cream of which would have from 1 to 2 milligrams of iron per kilo, while the butter in controls, however carefully made, would show as much or in most cases more than the cream, to say nothing of the amount of iron found in the buttermilk and wash water. The possible error of sampling when working on these small amounts also tends to minimize the value of the percentage relations.

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[1] Kooper, W. D. Loc. cit.

Following are some of the results as found, the milligrams per kilo being accurate but the total weights of iron only approximated:

TABLE 9.—*Relation between iron added to cream and the iron found in butter, buttermilk, and wash water.*

Butter No.	Cream.		Butter.			Buttermilk.			Wash water.		
	Iron added.	Total iron added.	Iron found.	Total iron.	Total iron found.	Percentage of added iron.	Total iron.	Percentage of added iron.	Iron found.	Total iron.	Percentage of added iron.
	Mgs. per kilo.	*Mgs.*	*Mgs. per kilo.*	*Mgs.*	*Per cent.*	*Mgs. per kilo.*	*Mgs.*	*Per cent.*	*Mgs. per kilo.*	*Mgs.*	*Per cent.*
8	1,000	2,736.0	180.90	172	6.3	1,189.00	2,310.0	84.40	17.70	35	1.30
13	500	1,310.0	84.00	77	5.9	510.20	962.0	73.40	36.40	73	5.60
19	200	9,613.0	29.40	402	4.2	69.60	2,554.0	26.57	92.60	4,222	42.92
27	100	4,808.0	11.40	140	2.9	61.20	2,252.0	46.85	2.90	137	2.90
38	50	2,296.0	4.29	66	2.8	24.10	914.0	39.80	15.60	711	30.97
81	50	2,269.0	15.60	212	9.3	39.40	1,253.0	55.22	1.20	27	1.20
51	20	862.0	7.78	85	9.9	8.89	304.0	35.27	.40	10	1.20
[1] 55	20	862.0	8.60	112	13.0	18.90	605.0	70.20	7.20	164	23.95
43	(2)	40.0	3.03	33	82.5	2.17	58.7	146.30	1.44	33	82.50
85	(3)	103.2	2.22	39	37.8	1.73	75.0	72.70	.97	22	21.30

[1] Iron in contact twenty minutes.
[2] Control. Found 1 milligram per kilo.
[3] Control. Found 1.98 milligrams per kilo.

Although from these results no definite relationship can be stated between the amount of iron added to the cream and the amount of iron found in the butter, buttermilk, and wash water, yet in a general way it might be stated that a relatively small part of the iron goes into the butter as compared with the buttermilk, which seems to take most of the iron, and in which the presence of a flavor due to the iron was most noticeable.

Distribution of iron between fat and curd solution.—When this work was first started it was thought that the amounts of iron taken up by the fat of the butter were negligible, and so in the analyses of butter the curd solution only was used for analysis. Later analyses were made of the fat as well as the curd solution on 22 samples of butter made at Troy, Pa., during the summer of 1911, with the following results, basing the fat content in butter at 80 per cent, since all the fat was not separated from the curd solution and the fat contained small particles of curd. The fat was not filtered, and so in some instances contained small particles of curd, which may account for a variance in iron content of the fat.

TABLE 10.—*Iron content of butter, curd, and fat.*

Butter No.	Iron added to cream.	Total iron found in butter.	Percentage of total iron in fat.	Percentage of total iron in curd.	Iron in fat.	Iron in curd.
	Mgs. per kilo.	*Mgs. per kilo.*	*Per cent.*	*Per cent.*	*Mgs. per kilo.*	*Mgs. per kilo.*
120	0	6.64	7.90	92.10	0.66	30.59
122	20	25.60	22.70	87.30	7.27	98.80
125	0	6.92	9.40	90.60	.82	31.32
127	10	10.99	3.25	96.75	.45	53.18
132	0	9.11	4.20	95.80	.48	43.64
134	5	7.20	10.50	89.50	.95	32.25
140	0	8.24	8.40	91.60	.87	41.38
142	2	7.40	12.00	88.00	1.11	32.55
148	0	7.56	12.00	88.00	1.13	33.27
150	1	8.79	10.70	89.30	1.18	39.28
157	0	5.45	15.50	84.50	1.06	23.01
159	0	5.09	32.40	67.60	2.06	17.21
164	0	4.62	27.50	72.50	1.59	16.75
166	0	5.71	17.90	82.10	1.28	23.43
171	0	4.04	19.60	80.40	.99	16.22
173	0	7.76	13.10	86.90	1.27	33.70
193	0	4.78	9.39	90.61	.56	21.73
194	(1)	6.33	7.44	92.56	.59	29.29
201	0	6.77	8.03	91.97	.68	31.11
203	(2)	6.93	10.00	90.00	.89	31.21
205	0	5.18	8.91	91.19	.58	23.61
207	(2)	9.11	7.69	92.31	.88	42.07

[1] Rusted can. [2] Iron strip.

In this table, as in any table of this kind, the percentage relation is relatively unimportant. The question of the actual amount of iron found in the fat is of much greater importance. An average of the control butters, of which there are 14 in the above table, will show a content of 1 milligram of iron per kilo of butter fat, a very small amount that could be disregarded in most cases. In normal butters made under proper conditions where the total iron content is about 1.3 milligrams per kilo, even a difference of 0.5 milligram of iron in a pound of butter would be noticeable on a comparative basis between the fat and curd content, but when total iron is being considered so small an amount as 0.5 milligram of iron could easily be discarded in the calculation.

THE INFLUENCE OF IRON ON FLAVOR.

The ideal condition for the solution of this problem would of course be to have butter made absolutely free from iron while known amounts of iron, or any other metal as the case might be, could be added to a portion of the cream used in making this metal-free butter. This could be done only by drawing the milk samples directly into glass vessels, skimming by hand, and ripening and churning in small quantities in glass. This method of procedure seemed impracticable, since enough butter could not be made to satisfy all the requirements of the experiment. The first few samples were, however, churned in a tall glass jar by shaking by hand, but proved unsatisfactory in that only a small amount could be made and the butter was not very good. The best thing to be done under the circumstances was to control conditions as carefully as possible and avoid any undue contact with iron during the whole process of butter making. The method of butter making has been described. The butters were scored for the first time in most cases very shortly after making, being kept in cold storage until scored. It will be noticed that the butters made at Albert Lea, Minn., were scored by the Fox River Butter Co. and those made at Troy, Pa., or Washington, D. C., were scored by Mr. Fryhofer and Mr. Smarzo, of New York City. For this reason these scores are not comparable, as in our experience there is considerable variance between the scores and methods of scoring even among professional butter scorers. Following is a table showing the butter scores. In every case the butter to which metal has been added is followed by a control butter, made at the same time under the same conditions.

TABLE 11.—*Influence of iron on flavor of butter.*

Butter No.	Data on ripened, pasteurized cream.					Butter.		
	Iron content normal in cream.	Iron added as ferrous sulphate.	Duration of contact.	Acidity at time of churning.	Iron found in butter.	Age of butter when scored.	Score.	Remarks.
	Mgs. per kilo.	*Mgs. per kilo.*	*Hours.*	*Per cent of lactic acid.*	*Mgs. per kilo.*	*Days.*		
[1] 19	....	200	22	....	29.4	7	85.0	Very fishy.
						187	85.0	Do.
[1] 23	10.90	0	....	0.53	8.3	7	92.5	Coarse, unclean.
						187	85.0	Very fishy.
27	3.84	100	23	.77	11.4	11	92.0	Oily.
						184	85.0	Very fishy.
31	3.84	0	....	.65	2.59	11	93.5	
						184	85.0	Do.
39	.40	50	23	.73	4.29	14	86.0	Fishy.
						179	85.0	Very fishy.
[1] 35	.40	0	....	.73	1.70	14	87.0	Fishy.
						179	85.0	Very fishy.
[1] 47	.99	25	23	.53	26.5	9	87.0	Slightly fishy.
						175	85.0	Very fishy.
[1] 43	1.00	0	....	.51	3.03	9	92.0	Coarse.
						175	86.0	Very fishy.
[1] 81	2.76	50	22	.60	15.6	16	93.5	Clean.
						160	88.0	Oily, unclean.
[1] 77	2.76	0	....	.62	2.49	16	94.0	
						160	88.0	Fishy.
122	2.93	20	21	.57	25.6	3	86.0	Very oily; very fishy.
						44	85.0	Do.
						116	82.0	Rank, oily, and fishy.
120	2.90	0	....	.58	6.64	3	93.0	Clean.
						44	84.5	Very fishy.
						116	80.0	High acid, clean, rank fishy.
127	2.11	10	23	.49	10.99	5	84.0	Oily, metallic, unclean, rancid.
						42	85.0	Oily, metallic, very salvy.
						114	84.0	Very oily, metallic.
125	2.48	0	....	.48	6.92	5	88.0	Oily, slightly metallic, unclean.
						42	85.0	Oily, metallic.
						114	84.0	Very oily, metallic.
134	1.64	5	21½	.59	7.20	3	91.5	Metallic, unclean.
						39	86.5	Metallic, stale.
						111	83.0	Very fishy.
132	1.64	0	....	.55	9.11	3	94.0	Very clean.
						39	85.5	Fishy.
						111	82.0	Very high acid, clean, very fishy.

[1] Butter made at Albert Lea, Minn. Scored by Fox River Butter Co. All other butters made at Troy, Pa.

TABLE 11.—*Influence of iron on flavor of butter*—Continued.

Butter No.	Data on ripened, pasteurized cream.					Butter.		
	Iron content normal in cream.	Iron added as ferrous sulphate.	Duration of contac.	Acidity at time of churning.	Iron found in butter.	Age of butter when scored.	Score.	Remarks.
	Mgs. per kilo.	*Mgs. per kilo.*	*Hours.*	*Per cent of lactic acid.*	*Mgs. per kilo.*	*Days.*		
142	1.17	2	17	.59	7.40	2	91.0	Slightly metallic.
						47	87.0	Very metallic.
						105	88.0	Oily.
140	1.17	0	....	.60	8.24	2	94.5	Slightly metallic aroma, clean.
						47	88.0	Metallic.
						105	83.0	Very fishy, clean, low acid.
150	.45	1	20	.60	8.79	6	86.0	Very oily and fishy.
						45	86.0	Oily and fishy.
						103	85.0	Do.
148	.74	0	....	.60	7.56	6	89.0	Milky
						45	87.0	Slightly fishy.
						103	86.0	Fishy, clean, high acid.
[1] 93	....	20	....	....	5.80	11	86.0	Oily, very fishy.
						128	86.0	Fishy.
[1] 92	....	0	....	....	3.41	11	91.5	
						128	91.0	
223	....	[2] 10	20½	.668	7.37	4	84.0	Unclean, stale, oily.
						29	84.0	Unclean, metallic, gritty.
						61	84.0	Rank, metallic.
222	....	0	....	.552	3.39	4	86.0	Stale, oily.
						29	86.0	Very oily, metallic.
						61	86.0	Oily, metallic.
225	....	[2] 5	21	.66	5.4	4	88.0	Do.
						27	86.0	Very oily.
						59	84.0	Very metallic and fishy.
224	....	0	....	.55	2.15	4	90.0	Slightly metallic.
						27	87.0	Unclean, oily.
						59	87.0	Oily, metallic.
227	....	[2] 2.5	21	.60	3.59	4	87.0	Tainted, very oily.
						25	87.0	Oily.
						57	85.0	Very oily, metallic.
226	....	0	....	.54	2.85	4	93.0	Good butter.
						25	93.0	
						57	89.0	Old flavor.
229	....	[2] 2	19½	.44	1.61	7	88.0	Very metallic.
						22	87.0	Oily, metallic.
						54	85.0	Very metallic.
228	....	0	....	.42	1.89	7	92.0	Somewhat oily, coarse.
						22	92.0	
						54	88.0	Oily, trifle fishy.
231	2.99	[2] 1	20¾	.46	1.63	5	94.0	Good, clean, creamy.
						20	93.0	
						52	86.0	Very fishy.
230	2.73	0	....	.52	2.16	5	92.0	Somewhat oily, coarse.
						20	92.0	
						52	88.0	Little fishy.

[1] Butter made at Albert Lea, Minn. Scored by Fox River Butter Co. All other butters made at Troy, Pa.

[2] Iron added as lactate.

In Table 11 it will be noticed that in every instance on the first scoring the butters to which iron had been added scored lower than their controls. This holds in most cases on the second and third scoring, the most noticeable feature being that the butters to which iron has been added show the deterioration much faster than the control butters. After the butters have deteriorated to a score of 85 or lower, the butter is so poor that a difference of a point or two in the score really does not indicate a very great difference in the quality of the butter. A great many of the butters became fishy, and where both were not scored fishy at the same time it will be noticed that the control butter was the last to become "fishy," though in one or two instances the control was scored "fishy," while the other butter was not marked fishy at all. A very noticeable feature about these butters is the production of a very oily flavor. This was present in most amples that were marked fishy and seems to be a stepping stone to the fishy flavor.

THE INFLUENCE OF COPPER ON FLAVOR.

In the work on copper only the physical changes will be considered, as considerable difficulty was experienced in making accurate determinations of the very small amounts of copper present in the butter.

These butters were made in exactly the same way as the butters showing the influence of iron. The cream was all very carefully handled to avoid contact with copper, and divided into two portions, which were treated in exactly the same manner, excepting that to one-half of the cream, copper in the form of a solution of copper sulfate or lactate was added in amounts varying from one-half to 20 milligrams per kilo of cream. The cream was ripened and churned and the butter stored in glass jars without metal parts, or in ash tubs, in 1912, and scored at intervals. The changes in the butter are shown in the following tables:

TABLE 12.—*Influence of copper on butter.*

Butter No.	Data on ripened and pasteurized cream.			Butter.		
	Copper added as sulfate.	Duration of contact.	Acidity at churning.	Age on scoring.	Score.	Remarks.
	Mgs. per kilo.	*Hours.*	*Per cent of lactic acid.*	*Days.*		
[1] 89	20	19	0.51	14	90.0	Very fishy.
				158	85.0	Do.
[1] 85	0	....	.60	14	92.5	Oily.
				158	86.0	Very fishy.
[2] 173	4	22	.60	5	85.0	Oily, fishy, unclean.
				38	85.0	Oily, fishy.
				96	80.0	Rank, fishy, clean, high acid.
[2] 171	0	....	.60	5	91.0	Oily.
				38	90.0	Slight metallic.
				96	86.0	Fishy, clean, low acid.
[2] 166	2	....	.56	2	87.0	Oily, unclean, rancid.
				40	84.0	Very oily, fishy.
				98	80.0	Rank, oily and fishy, unclean, low acid.
[2] 164	0	....	.52	2	93.0	Slight metallic.
				40	87.0	Oily, metallic.
				98	87.0	Oily.
[2] 159	1	....	.51	4	85.0	Oily, metallic, stale.
				42	84.0	Very oily and fishy.
				100	80.0	Rank, fishy, unclean, low acid.
[2] 157	0	....	.50	4	91.0	Slight oily.
				42	86.0	Very oily, fishy.
				100	82.0	Very oily, fishy, clean, high acid.
[3] 235	[4] 5.0	19	.36	3	86.0	Very oily and metallic.
				18	84.0	Oily and fishy.
				50	84.0	Rank, fishy.
[3] 234	0	....	.385	3	92.0	Somewhat oily and coarse.
				18	89.0	Oily.
				50	89.0	Old flavor.
[3] 237	[4] 2.5	19	.415	2	88.0	Oily and metallic.
				15	87.0	Unclean, oily.
				47	84.0	Rank, fishy.

[1] Butter made at Albert Lea, Minn., 1910.

[2] Butter made at Troy, Pa., 1911.

[3] Butter made at Troy, Pa., 1912.

[4] Copper added in form of copper lactate.

TABLE 12.—*Influence of copper on butter*—Continued.

Butter No.	Data on ripened and pasteurized cream.			Butter.		
	Copper added as sulfate.	Duration of contact.	Acidity at churning.	Age on scoring.	Score.	Remarks.
	Mgs. per kilo.	*Hours.*	*Per cent of lactic acid.*	*Days.*		
[1] 236	0	....	.58	2	92.0	Trifle coarse, slightly tainted.
				15	91.0	Slight unclean.
				47	86.0	Tallowy flavor.
[1] 239	[2] 1.5	18¾	.376	2	92.0	Slight oily and metallic.
				13	92.0	Slight oily.
				45	86.0	Metallic and fishy.
[1] 238	0	....	.355	2	94.0	Good and clean.
				13	94.0	
				45	93.0	Clean.
[1] 241	[2] 1.0	21	.40	3	88.0	Very oily and metallic.
				43	87.0	Metallic.
[1] 240	0	....	.34	3	91.0	Trifle metallic.
				43	91.0	Old flavor.

[1] Butter made at Troy, Pa., 1912.

[2] Copper added in form of copper lactate.

From Table 12 it will be seen that in every instance the scores on the control butters were better than the scores on the butter made from cream to which copper had been added, even in the small amount of 1 milligram of copper per kilo of cream.

Unfortunately, the "Remarks" on the butter do not show any definite characteristics that can be attributed to the copper. The control butters, too, show deterioration in storage, though they seem to keep better than the butters made from cream to which the copper was added. On the second scoring after 40 days in storage most of the butter to which copper had been added showed a fishy flavor and after three months a very decided rank, fishy flavor that was unmistakable, and was called by scorers decided mackerel flavor. These butters were all made during the summer months.

An experiment to show the effect of having the cream stand in contact with a small surface of copper for a long time was made by having a vat of cream ripened in contact with two sheets of bright copper each 2 by 6 inches. The sheets were placed on edge in the bottom of the vat during the process of ripening. The result of this is shown in the following table:

TABLE 13.—*Effect of copper on flavor of butter.*

Butter No.	Cream.		Duration of contact.	Age.	Score.	Remarks.
	Normal acidity.	Churning acidity.				
	Per cent.	*Per cent.*	*Hours.*	*Days.*		
256	0.17	0.355	....	1	93	
				31	91	Trifle old flavor.
257	.17	.37	21	1	91	Trifle oily.
				31	88	Metallic.

The difference in flavor is marked in the fresh butter but more marked in storage butter.

Another experiment to show the effect on the flavor of the butter, by having the cream come in contact with a large surface of copper for a short time, was made by pasteurizing the cream in two parts. One part was pasteurized in a No. 3 Peerless pasteurizer, the copper lining being completely covered with tin. The second part was pasteurized in a No. 5 Peerless pasteurizer, the tin coating of which had been worn off by continued usage, leaving the cream exposed to a surface of copper during the process of pasteurization. The duration of contact with the copper was only a few seconds, though the surface was quite large. The temperature of pasteurization was about 60° C.

The results of this experiment are found in the following table:

TABLE 14.—*Comparison of the effect of tin and copper on the flavor of butter.*

Butter No.	Pasteurizer.	Acidity of cream before pasteurization.	Temperature of pasteurization.	Acidity at churning.	Age.	Score.	Remarks.
		Per cent.	° *C.*	*Per cent.*	*Days.*		
245	Tin......	0.18	60	0.55	2	91	Slight oily.
					39	92	Good.
246	Copper..	.18	60	.50	2	87	Oily, stale, metallic.
					39	85	Very fishy.
252	Tin.....	.19	60	.52	1	92	Slight oily.
					33	89	Oily.
253	Copper..	.19	60	.47	1	89	Do.
					33	84	Very fishy.

These two experiments show very plainly the deteriorating effect of poorly tinned pasteurizers, for aside from this all other conditions were exactly alike during the complete process of butter manufacture. Considering the short duration of contact, the change in the flavor of the butter even when fresh is very marked. The effect of copper even in small amounts seems to cause more marked changes in butter flavor than iron, with a marked tendency toward a fishy flavor in storage.

CONTAMINATION OF CREAM WITH IRON FROM CONTAINERS.

For this experiment a lot of cream was divided into two portions, one portion being held in a clean can and the other in a can which showed many rust spots. This was the most rusted of all the cans that were used for the handling of cream at the Troy Creamery Co., of Troy, Pa. However, this showed only small spots of rust on the bottom of the can. This raw cream was ripened without the addition of a starter at room temperature. The temperature, acidity, and iron content are as follows:

TABLE 15.—*The absorption of iron from rusty can.*

Duration of contact.	Clean can.			Rusted can.		
	Temperature.	Acidity.	Iron found.	Temperature.	Acidity.	Iron found.
Hours.	° *F.*	*Per cent.*	*Mgs. p. kilo.*	° *F.*	*Per cent.*	*Mgs. p. kilo.*
0	66	0.114	1.045	66	0.114	1.045
2	67	.101	1.031	67	.120	1.132
4	67	.146	1.539	67	.158	1.772
6	67	.177	1.028	67	.176	1.265
8	68	.202	1.677	68	.212	1.129
14	66	.412	.792	66	.422	1.627
21	66	.561	1.082	66	.561	1.459
26	64	.581	.951	56	.568	1.187
32	52	.634	1.082	57	.624	1.257
48	44	.632	1.185	57	.638	2.381
	Butter made from above cream		4.78.	Butter made from above cream		6.33.

Another experiment on the same basis but without the acidity of the cream at the various intervals gave the following results, from a cream having a normal iron content of 0.9 milligram per kilo and an acidity of 0.16 per cent lactic acid.

TABLE 16.—*Effect of rusty can on the flavor of butter.*

Butter. No.	Iron in butter.	Cream contact in cans.	Iron content in ripened cream.	Churning acidity.	Butter.		Remarks.
					Age.	Score.	
	Mgs. p. kilo.	*Hours.*	*Mgs. p. kilo.*	*Per cent.*	*Days.*		
259	1.37	15	4.31	0.51	19	92	Slight oily.
					29	89	Trifle metallic, oily.
260	1.60	15	4.35	.49	19	88	Oily, metallic.
					29	86	Unclean, oily.

From Table 15, it is seen, as would be expected, that the acidity of cream increases with the length of time it is held, though there is no material difference in the rate of increase between the two samples. The cream in the rusted can does not show any marked increase in iron content over that in the clean can. The difficulty in getting an accurate sample of the cream after standing long enough to thicken may account for the variation from what might have been expected. At the end of 48 hours the cream from the rusted can showed an iron content of 1.2 parts per 1,000,000 more than the cream from the clean can. The butters made from these creams checked very closely, as the butter made from the cream held 48 hours in the rusted can showed 1.55 parts per 1,000,000 more than the butter made from the cream held 48 hours in a clean can.

In another instance to find whether cream on standing in contact with iron rust would take up iron, a lot of cream was divided into four parts, each placed in a clean can, and a strip of rusted iron tape one-half inch wide and 24 inches long (giving a surface of 24 square inches) was placed in two of these cans. Two cans, one with and one without the iron, were ripened at room temperature for 21 hours, and two cans, one with and one without iron, were held in cold storage at 32° F. for 21 hours. Butter was made from each of these four samples of cream. There was no starter added to this cream. The cream from which these four lots were taken had acidity of .223 and iron content of 1.25 milligrams per kilo.

TABLE 17.—*Data on cream ripened in contact with rusty iron.*

No.	Cream.			Butter.		
	Temperature.	Acidity.	Iron content.	Butter No.	Iron content.	Score.
	° F.		*Mgs. per kilo.*		*Mgs. per kilo.*	
1	32	0.385	1.53	1	6.77	94
[1] 2	32	.368	1.81	2	6.93	91
3	66	.655	.90	3	5.18	94
[1] 4	66	.670	11.32	4	9.11	91

[1] In contact with iron tape.

From this table, although it does not show the acidity and iron content at intervals as in Table 15, still it shows here that with the development of acidity the iron is taken up by the cream. This is very marked in cream and butter No. 4, the iron content in both being very high as compared with their respective controls. The effect of the iron is also very marked in the butter scores, the controls (Nos. 1 and 3) scoring three points higher than the ones to which the iron had been added.

In the first experiment Mr. Larson, superintendent of the Troy Creamery Co., said he could taste the iron in the cream after 32 hours' contact, and in the second experiment the cream in contact with iron ripened at room temperature showed a bitter metallic taste.

In every case the butter made from cream which had stood in contact with iron rust showed a peculiar taste and was easily picked out from a lot of samples. The taste was, however, most noticeable in the buttermilk, to which it gave a decided metallic taste.

In Table 15 the difference in the amounts of iron found in the cream are very small, in only one case being more than 1 milligram of iron per kilo of cream. Taking into consideration the possibility of error in sampling a very thick cream, these small differences do not seem to be enough to warrant any definite conclusions as to the absorption of iron by the cream. It will be noticed in Table 11 that all the control butters made by us at Troy, Pa., have a very high iron content, as compared with control butters made by us at Albert

Lea or made by the Troy Creamery Co. at Troy. As the wash water was tested and the cream did not show a high iron content, the churns are the only means whereby iron might be introduced into the butter. Although these churns were taken apart and scraped, sandpapered, and thoroughly cleaned before being used at Troy, it is possible that there were some rust spots on the iron bolt heads and plates coming in contact with the cream, and that the iron was attacked at these points by the high acid cream and the iron taken up by the butter. Unfortunately the butter samples were not analyzed at the time the butter was made, otherwise this error would have been noticed in the chemical results and corrected before continuing the work. The high iron content of the butters made at Troy, Pa., seemed to show conclusively that there was an error by contamination at some step in the process of butter making. The only check possible on the butter itself was by analysis of the butter made by the Troy Creamery Co. in their large churn. In most cases the cream for the experimental butter was selected from the best cream brought to the creamery, while the cream used in the creamery proper was the regular run of cream as brought in by the farmers and from the several skimming stations. In this way the butter from the creamery proper, if the fault were in the cream, should show a higher iron content than the experimental butter. The cream used in the experimental creamery was analyzed for iron (in most cases) at three stages; first, raw sweet cream; second, immediately after pasteurizing (to determine whether there was any iron exposed in the pasteurizer or cooler), and, third, after ripening in the ripening vats to determine whether there was any iron taken up in the vats. The butter was then analyzed, thus giving the last stage in the process of butter making.

The butter made in 1912 at Troy, Pa., was churned in new No. 5 Bestov box churns, and worked on a table worker, eliminating this contamination by iron in the churn. The butter for scoring was packed in 10-pound ash butter tubs instead of glass jars in order to avoid injuring the body of the butter in packing.

TABLE 18.—*Iron content of cream and controls.*

[Milligrams per kilo.]

Butter.	Raw cream.	Pasteurized cream.	Raw ripened cream.	Pasteurized ripened cream.	Curd as 100 per cent of butter.	Curd as 20 per cent of butter.	Fat as 80 per cent of butter.
120 E	...	...	...	2.93	6.12	30.59	0.66
125 E	2.11	2.48	...	2.57	6.26	31.32	.82
132 E	1.89	1.49	...	1.64	8.73	43.64	.48
140 E	1.19	1.12	...	1.17	7.54	41.38	.87
148 E	.45	.55	...	.74	6.65	33.27	1.13
157 E	1.47	...	...	1.59	4.60	23.01	1.06
164 E	1.46	...	...	1.63	3.35	16.75	1.59
171 E	1.94	...	...	1.44	3.24	16.22	.99
201 E	1.25	...	1.53	...	6.22	31.11	.68
205 E	1.75	...	.90	...	4.72	23.61	.58
135 T	...	...	...	...	1.12	5.59	...
136 T	...	...	...	...	1.16	5.81	...
143 T	...	...	...	...	1.25	6.26	...
151 T	...	...	...	...	.96	4.81	...
152 T	...	...	...	...	1.19	5.97	...
160 T	...	...	...	...	.89	4.47	...
161 T	...	...	...	...	1.21	6.05	...
167 T	...	...	...	...	[1] 1.55	[1] 7.77	...
168 T	...	...	...	...	[1] 1.31	[1] 6.52	...
195 T	...	...	...	...	[1] 1.50	[1] 7.51	...
196 T	...	...	...	...	[1] 1.79	[1] 8.96	...
197 T	...	...	...	...	[1] .99	[1] 4.96	...
198 T	...	...	...	...	[1] 2.35	[1] 11.74	...
[2] 224	...	...	...	...	2.15	...	...
[2] 226	...	...	...	...	2.85	...	...
[2] 228	...	...	...	...	1.89	...	...
[2] 230	...	...	...	2.73	2.16	...	...
[2] 234	...	...	...	...	2.04	...	...
[2] 236	...	...	...	...	3.16	...	...
[2] 238	...	...	...	...	3.50	...	...
[2] 240	...	...	...	...	3.59	...	...
[2] 246	.94	2.04	...	...	1.95	...	...
[2] 247	...	...	...	...	1.36	...	...
[2] 248	...	...	...	...	1.14	...	...
[2] 252	...	2.01	...	...	1.41	...	...
[2] 253	...	1.14	...	...	1.41	...	...
[2] 256	1.67	...	...	...	3.40	...	...
[2] 257	1.67	1.10	...	...	6.63	...	...
[2] 259	...	.9	...	...	1.37	...	...
[2] 263	...	...	...	4.31	2.69	...	...
[2] 264	...	...	...	4.35	1.45	...	...

E Butter made in experimental creamery, Troy, Pa., 1911.
T Butter made by Troy Creamery Co., 1911.
[1] Curd burned in porcelain.
[2] Butter made in experimental creamery, Troy, Pa., 1912.

Table 18 is arranged to show the iron content found in the cream and butter made in the experimental creamery and also, for comparison, the iron content of the butters made by the Troy Creamery Co. In these analyses the fat was disregarded and the iron found in the curd solution used as the total iron in the butter. It will be noticed in the column, "Fat as 80 per cent of the butter" that the iron content averages 0.89 milligram per kilo. As the usual charge of butter was 500 grams, the total iron in fat would be less than 0.4 milligram of iron, which is a very small and almost negligible quantity.

Ten samples of control butter made in the experimental churns gave an average iron content of 5.74 milligrams of iron per kilo of butter using the curd solution only and calculating as butter, while 13 samples of butter made by the Troy Creamery Co. in their large churn during the same period showed an average iron content of 1.33 milligrams of iron per kilo of butter, using curd solution only and calculating as butter. The same cream, with a possible advantage in favor of the experimental cream, the same salt, and the wash water from the same source, were used in the manufacture of both the experimental and the Troy Creamery Co.'s butter, so that the only point of entry for the increased iron content in the experimental butters was in the churns. This might possibly account for the deterioration in the control butters made in the experimental creamery in 1911, and although these results detract from the results in the other experiments, still the value of the evidence to show that iron may be taken up in the churn is of great importance to the butter maker. Rusty boltheads, plates, or other castings should be carefully guarded against by the butter maker.

THEORETICAL CONSIDERATIONS.

Having ascertained definitely, partly from the empirical observations of others, and partly from the experimental data obtained on butter containing added iron, that iron itself lowers the keeping quality of butter, it was desirable to find out how iron affects butter.

That the iron acts catalytically in an oxidative reaction at once suggests itself. As has been shown, butter made by the usual methods contains gases in the proportion of approximately 10 cubic centimeters in 100 grams of butter. It seems possible that a few parts of iron per million parts of butter, present in a finely divided, colloidal condition might be able to transfer slowly some of the inclosed oxygen to any one of the oxidizable substances present. It is of course well known that in the presence of a peroxid such as hydrogen peroxid the iron will rapidly transfer oxygen from the peroxid to an oxidizable substance. A transfer of oxygen such as this is often referred to as peroxidase action and the substance through which the transfer is brought about, the colloidal iron compound in this case, is called a peroxidase. It is also well known, at least the statement is often seen in the literature, that peroxidases can transfer oxygen only from peroxids and hence are inactive in the absence of peroxids. Kastle,[1] in discussing the mode of action of peroxidase, states: "According to Bach and Chodat[2] the peroxidases exert not the slightest oxidizing action in the absence of the peroxid." It is perhaps to be regretted that this statement was not accompanied with another to the effect that this conclusion follows from an experiment in which Bach and Chodat[1] made observations on oxygen absorption for a period of 24 hours. Bach and Chodat,[2] in support of their contention that peroxidases are without action in the absence of peroxids, quote the work of Linossier[3] which was likewise a series of observations on peroxidase action covering only very short periods of time.[4]

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[1] Kastle, J. H. The oxidases and other oxygen-catalysts concerned in biological oxidations. United States Treasury Department, Public Health and Marine-Hospital Service, Hygienic Laboratory, Bulletin 59. Washington, 1910. See p. 117.

[2] Bach, A., and Chodat, R. Ueber Peroxydase. Berichte der Deutschen Chemischen Gesellschaft, vol. 36, no. 3, pp. 600-605. Berlin, Feb. 21, 1903.

It may be true that peroxidases in the presence of air are inactive when their activities are measured for intervals of 24 hours. But in the case of cold-storage butter, in which iron and air may interact for several months, the possibility that oxidative action may take place is not excluded, in spite of the fact that there is at present no reason to suppose that peroxids are present in butter.

The experiments here described on the oxidation of lactose in milk through the action of iron salts are in many respects similar to those made in recent years by several investigators whose work throws some light on the subject.

Löb and Pulvermacher[5] studied the action of gaseous oxygen and of hydrogen peroxid on dextrose and sucrose. They used as an oxidative agent a preparation made by extracting pig pancreas with alcohol and adding iron to the alcohol filtrate. The precipitate of iron-pancreatic material was dried and used in the experiments. In 24 to 48 hours this substance could oxidize dextrose in aqueous solution either in the presence of hydrogen peroxid or by the aid of a stream of air or oxygen. Sucrose was also oxidized by hydrogen peroxid and iron-pancreas powder, but to a much less extent. They suggest the necessity of the inversion of the sugar before oxidation can take place.

Battelli and Stern[6] and Harden and MacLean[7] studied oxidation in isolated, hashed animal tissues. These investigators used such material as hashed muscle, suspended in water. The suspensions were placed in a flask filled with gaseous oxygen. The substance to be oxidized was added to the suspension and the flasks were connected with an apparatus for measuring the amount of oxygen absorbed.

According to Battelli and Stern, succinic acid is very easily oxidized in a very few hours under the conditions of their experiment. Harden and MacLean repeated some of the experiments of Battelli and Stern and found that the oxidation of succinic acid was not as vigorous as Battelli and Stern had found.

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[1] Bach, A., and Chodat, R. Loc. cit. See pp. 604–605.

[2] Bach, A., and Chodat, R. Loc. cit. See p. 605.

[3] Linossier, G. Contribution á l'étude des ferments oxydants. Comptes Rendus Hebdomadaires des Séances de la Société de Biologie, vol. 50, no. 12, pp. 373–375. Paris, Apr. 1, 1898.

[4] The reference to Linossier given by Bach and Chodat is incorrect; the reference by Kastle is correct.

[5] Löb, Walther, and Pulvermacher, Georg. Über die oxydative Zuckerzerstörung unter der Einwirkung von Organpräparaten. Biochemische Zeitschrift, vol. 29, no. 4/5, pp. 316–346. Berlin, Nov. 22, 1910.

[6] Battelli, F., and Stern, L. Die oxydation der Bernsteinsäure durch Tiergewebe. Biochemische Zeitschrift, vol. 30, no. 1/2, pp. 172–194. Berlin, Dec. 23, 1910.

[7] Harden, Arthur, and MacLean, Hugh. The oxidation of isolated animal tissues. Journal of Physiology, vol. 43, no. 1, pp. 34–45, Sept. 11, 1911.

There are several reasons why the results on peroxidase action obtained by one investigator might not be the same as those obtained by another on material intended to represent exactly the material previously used. The activity of peroxidases is influenced by so many conditions that an exact reproduction of any particular mixture is perhaps more difficult than might at first be supposed. Furthermore, according to Wolff,[1] the iron peroxidase is very specific in its action, its specificity being determined by the other substances which may be present. Certain iron salts or combinations of such may oxidize one phenol and be incapable of oxidizing any other.

The results obtained in experiments on the oxidation of such substances as dextrose must be interpreted carefully, as Levene and Meyer[2] have pointed out. They showed that in a sugar solution the reducing power of which had been lowered by the combined action of muscle plasma and pancreatic extract the reducing power was restored to its original height by boiling under a return condenser for two hours in the presence of 1 per cent hydrochloric acid and that a substance having the properties of a biosazone could be obtained from the above described solution. So that loss of reducing power does not necessarily imply destruction of sugar; it may mean a simple polymerization.

The results of the above-mentioned investigations were used in planning the experiments that follow:

THE OXIDATION OF LACTOSE IN BUTTER.

For the purpose of ascertaining whether lactose which is ordinarily present in butter to the extent of about 0.1 to 0.2 per cent is being oxidized in cold-storage butter, with the production of substances having a disagreeable taste or smell, any one of several methods suggest themselves as possible. The lactose present in a lot of butter before and after storage may be estimated by any one of the well-known methods, or the oxidation products of lactose may be looked for in storage butter.

But the possible oxidation of lactose with the formation of off flavors might be brought about with such little change in the lactose content that the ordinary methods of analysis might be inadequate for the detection of the change. It was pointed out before (p. 6) that very small amounts of some substances are easily detected by the senses of taste and smell and that these amounts are smaller than are detectable by the best analytic methods of the present time. It was also pointed out (p. 15) that the separation of fat quantitatively from butter is difficult. This introduces a difficulty in the direct estimation of lactose in the butter curd solution.

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[1] Wolff, J. Relations entre les phénomènes oxydasiques naturels et artificiels. Annales de l'Institut Pasteur, vol. 24, no. 10, pp. 789-797. Paris, Oct. 25, 1910.

[2] Levene, P. A., and Meyer, G. M. On the combined action of muscle plasma and pancreas extract on glucose and maltose. Journal of Biological Chemistry, vol. 9, no. 2, pp. 97-107. Baltimore, April, 1911.

For these and still other reasons it was considered advisable to avoid attempting to detect directly very minute changes in the lactose content of storage butter. The problem was approached indirectly.

On account of the presence of sodium chlorid in butter in amounts varying from about 12 to over 30 per cent in the curd solution, care must be taken in applying the results of other investigators on peroxidases to this problem. It may be that the sodium chlorid is without effect. Obviously, only experimental data in which the peroxidase action in the presence of sodium chlorid is studied are directly applicable here.

One method used in studying (sample No. 25) the utilization of oxygen by iron in butter was similar in some respects to that used by Horbaczewski[1] and others in their studies of the utilization of atmospheric oxygen by oxidases of animal tissues.

Description of samples.—Several gallons of raw milk were obtained from a dealer and separated in the cream separator in the laboratory. To 8 liters of skim milk sodium chlorid was added, in the proportion of 180 grams of sodium chlorid to 1 liter of skim milk. Two and one-half liters of this sample (milk No. 25) were transferred to an 8-liter flask provided with a rubber stopper through which an inlet and outlet glass tube passed to permit the passage of the oxygen gas through the sample. Part of the sample was set aside. The milk in the flask was the material on which the experiment was made.

Methods and experimental procedure.—Before beginning the experiment the lactose content of the sample was determined by its reducing power and with the polariscope. In so far as no very great change in this quantity was expected, the greatest care was taken to obtain accurate results and uniformity of procedure.

For the gravimetric estimation of lactose the method described on pages 42, 48, and 119, Bulletin 107 (revised), of the Bureau of Chemistry was used. It is of course questionable whether the amount of copper reduced by a given weight of lactose in milk will be the same as that reduced by the same weight of lactose in milk containing 18 per cent of sodium chlorid. But what was sought was not the absolute amount of lactose present, but rather the difference, if any, between the amount of lactose present before and after a certain treatment of the sample.

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[1] Horbaczewski, J. Untersuchungen über die entstehung der Harnsäure im Säugethier organismus. Monatshefte für Chemie, Vol. 10, pp. 624–641. Vienna, 1889.

Six Gooch crucibles were prepared and used as described by Kendall.[1]

The weights of the Gooch crucibles after a determination were less than their weights before by an amount that varied between 0.4 and 1.2 milligrams. The average loss in weight for 19 determinations was 0.8 milligram. Only once did a crucible show a gain in weight, 0.3 milligram.

Although reagents (copper sulfate, sodium potassium tartrate, sodium hydroxid) of the highest purity were used, a slight reduction was always obtained in blank experiments made on an 18 per cent aqueous solution of sodium chlorid. The weight of cuprous oxid obtained in the blank determinations (9) varied from 3.6 to 9.1 milligrams, average 5.9 milligrams.

The reducing power of sample No. 25 was determined six times in duplicate during the course of the experiment. The duplicates differed by the following weights of cuprous oxid: 4.3, 0.4, 2.1, 0.2, 0.4, 0.8 milligrams. Very nearly 378 milligrams of cuprous oxid were always obtained in a determination, from which amount the amount of the blank determination was subtracted.

For the determination of lactose by the polariscope, the method given in Bulletin 107 (revised), Bureau of Chemistry, pages 118–119, was used: Eight cubic centimeters of acid mercuric nitrate was used as the precipitant for 131.6 grams of the sample in a 200 cubic centimeter flask. The filtrate was polarized in a 400-millimeter tube in a Ventzke polariscope. The readings divided by 4 give per cent of lactose, if it be assumed that the sodium chlorid was without effect on the rotatory power of the lactose. The results are collected in Table 19. Lactose containing one molecule of water of crystallization calculated from the polariscope readings was present to the extent of 4.75 per cent. The average weight of cuprous oxid found, 0.371 gram, corresponds to 0.2577 gram of lactose or 5.19 grams of lactose in 100 cubic centimeters sample No. 25.

The filtrate from the mercuric nitrate precipitation, although perfectly clear at first, soon becomes cloudy and unfit for reading in the polariscope. However, readings can be taken without interference by cloudiness if they are taken within one-half hour after filtering. The polariscope readings of the filtrates were found to undergo no change even after being allowed to remain in the laboratory for two weeks. After adding the precipitant and diluting to the mark the mixture was allowed to stand one hour. It was then filtered and the filtrate immediately polarized. Several days after, the filtrate was again filtered, a precipitate having formed in the meantime, and polarized. In this way several filtrates were repeatedly polarized at intervals of a few days without in any case detecting an appreciable variation in polariscope reading.

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[1] Kendall, Edward Calvin. A quantitative study of the action of pancreatic amylase. Columbia University, Dissertation, 1910. See p. 10.

After having determined the lactose in the sample No. 25, its specific gravity (in a 25 cubic centimeter pycnometer) was determined. Oxygen was then passed through the sample for 72 hours. The oxygen was passed from the oxygen tank into an 8-liter flask containing 3 liters of 18 per cent sodium chlorid solution and then through the milk. This was done so that the gas as it slowly bubbled through the milk would alter the concentration of the sample as little as possible. While the contact between gas and liquid was poor, it is almost certain that the liquid was saturated with the gas. About 25 gallons (not quite 100 liters) of oxygen passed through the sample in the 72 hours. Before each determination of lactose the specific gravity of the sample was determined and recorded. No significant variations were observed.

After the 72 hours' passage of the oxygen gas the lactose content of the sample was determined and found to have undergone no change. This showed, at least in this particular case, that the naturally occurring peroxidase in milk could not utilize molecular oxygen for the oxidation of lactose. From time to time tests for peroxidase were made, using tincture of guaiac and a few drops of a dilute solution of hydrogen peroxid. Peroxidase was present in the material throughout the experiment. Although always looked for, oxidase was not found in the several tests, except once, and that was probably due to some unaccountable error. The reagent, tincture of guaiac, was not the cause of the unusual positive test.

To sample No. 25 there was then added 8 grams of ferrous sulfate containing 7 molecules of water of crystallization ($FeSO_4 7H_2O$). One gram of metallic iron is present in 4.978 grams of this salt. On adding ferrous sulfate to the milk a very strong disagreeable odor was produced, suggesting putrefying protein. The odor was undoubtedly produced by the action of the iron on the milk, as the sample was odorless before the addition. The odor of the material throughout the experiment was always carefully noticed. (See p. 64.) The quantity of ferrous sulfate added was calculated to make one part of metallic iron present in 1,000 parts of milk. This is undoubtedly much more than is ever present in milk or butter, excluding the case where butter is in contact with iron rust, which has gone into solution but has not diffused very far into the butter mass. But the amount of iron was purposely made very high because the experimental time was to be much shorter than the storage period. The milk was allowed to stand one day after the addition of the iron, and the lactose determined. No change was noticed in this quantity nor was any change found after blowing oxygen through the sample for a second period of 72 hours. The acidity of the sample to phenolphthalein did not change during this time, nor were bacteria present during the experiment in numbers sufficient to affect the results. Oxygen was passed through the sample for 17 days longer with a decided drop in reducing power and polarization at the end of that period. This was due to bacterial action, as was shown by a suitable examination.

TABLE 19.—*Action of iron and oxygen on lactose in milk No. 25.*

No.	Treatment.	Reduction.		Polarization.	
		Date of determination.	Weight of Cu_2O.	Readings on Ventzke scale.	Date of readings.
			Grams.		
25	Original sample, containing sodium chlorid; age, 7 days	Mar. 28, 1911	0.3721	+19.0	Mar. 28
25	Repetition on same sample	Mar. 30, 1911	.3720	19.0	Mar. 30
25.1	After blowing oxygen through for 72 hours and letting stand 1 day	Apr. 4, 1911	.3703	18.9	Apr. 3
25.2a	Added ferrous sulfate and let stand 1 day	do	.3721	18.8	Apr. 5
25.2a	Repetition on part of the sample set aside until	Apr. 7, 1911	.3716		
25.2b	After blowing oxygen through sample for second period of 72 hours, a total of 144	do	.3692	18.6	Apr. 8
25.3	After 10 days slow and 7 days rapid blowing of oxygen through sample	Apr. 25, 1911	.2084	17.7 13.2	Apr. 17 Apr. 25

During the summer of 1910 three experiments, samples Nos. 1, 2, and 3, essentially similar to that on milk No. 25, were made. Air instead of oxygen was used. The results are not appreciably different from those in Table 19. Sample No. 1 was milk, samples 2 and 3 were skim milk; all three were soured before use in the experiments. Only the reduction was determined in these samples which, because of the formation of lactic acid, was lower than the reduction in sample No. 25. But the reduction did not change appreciably by the action of the air blown through the samples. The results were not as uniform as in Table 19, very likely because it is more difficult to sample accurately the sour milk containing particles of casein. After a few trials during the summer of 1910 on the best way of obtaining a uniform sample for reduction, it was found best to transfer the portion of the sample in the pycnometer (25 cubic centimeters) to the volumetric flask for clarification. In this way both the volume and weight of the portion used was known.

THE POSSIBLE OXIDATION OF LACTOSE IN STORAGE BUTTER BY A PEROXID.

It was stated before (p. 56) that there are at present no reasons for supposing that peroxids are present to any appreciable extent in butter. This statement is not free from assumption, for there is a possibility of the slow formation of an organic peroxid in butter. A review of the literature on the subject and an interesting discussion of the formation of organic peroxids by direct combination of the compound with molecular oxygen has been made by Kastle.[1] The detection of an organic peroxid in butter at any particular time might be practically impossible because of its almost immediate decomposition either by the catalase naturally present in unpasteurized cream butter or by iron almost always present, even in butter most carefully churned, to the extent of three or four parts per million of butter (see p. 54 for amounts of iron in butter) and yet the oxidative process may be taking place. Perhaps a careful analysis of the gas in butter will show whether any of the oxygen is being removed in this way. The work on the analysis of the gases in butter has been begun and some of the analyses are given on page 37.

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[1] Loc. cit.

For the reasons just mentioned the fact that no oxidation of lactose was detected in skim milk containing iron and through which oxygen was passed does not exclude the possibility of the slow formation of organic peroxids in butter and their subsequent oxidative action.

On the assumption that organic peroxids might be slowly formed in butter, and that such peroxids might be used by the peroxidase present for oxidation, a few experiments were made in which the polarization of skim milk was observed before and after the addition of hydrogen peroxid, with and without iron. The data are summarized in Table 20. One liter of each mixture was prepared from which portions were transferred to a 200 cubic centimeter flask for clarification and polarization.

It is evident that in these mixtures containing hydrogen peroxid and iron (Nos. 18, 19, and 23) there was a very appreciable lowering in the polarization. This lowering probably was not due to the easy reducibility of the mercury by the lactose, because in those filtrates containing hydrogen peroxid but no iron (Nos. 17 and 21) there was no lowering, although these filtrates contained unprecipitated mercury as well as the others. While there may be other possibilities, the most reasonable tentative conclusion to be drawn from the results of Table 20 is that the lactose was oxidized by the action of the peroxid and iron, and if there were peroxid formation in butter such oxidation of lactose might take place there. The experiments detailed in Table 20 were not expected to be conclusive; others are undoubtedly necessary.

TABLE 20.—*Oxidation of lactose by a peroxid and iron.*

Composition of mixtures.							Precipitated and filtered.........Jan. 26 Let stand still.......Jan. 29 Polarized.........Jan. 29	Jan. 31 Feb. 3 ...do......	Feb. 14 Feb. 17 ...do......	.... Feb. 20	.... Feb. 23	.... Mar. 4
Sample No.	Skim milk unpasteurized.	Hydrogen peroxid 3 per cent solution.	Water.	10 per cent ferric chlorid solution.	Toluol.	Sodium chlorid.						
	C. c.	*C. c.*	*C. c.*	*C. c.*	*C. c.*	*Grams.*	Sample—					
16	500	None.	490	None.	10	None.	No. 16........... +10.3	10.2	9.8	9.7	9.8	9.8
17	500	400	90	None.	10	None.	No. 17........... 10.3	10.3	10.1	10.1	9.6	9.6
18	500	400	65	25	10	None.	No. 18........... 3.3	6.7	5.5	3.6	3.6	3.5
19	500	300	65	25	10	180	No. 19........... 4.7	5.3	Sample lost.			

Composition of mixtures.						Precipitated and filtered.........Feb. 2 Let stand still.....Feb. 4 Refiltered and polarized.........Feb. 4	.... Feb. 6	Feb. 6 Feb. 9 ...do.....	.... Feb. 13	Feb. 14 Feb. 17 ...do.....	.... Feb. 17	.... Feb. 20	.... Feb. 23	.... Mar. 4
Sample No.	Skim milk unpasteurized.	Hydrogen peroxid 3 per cent solution.	Water.	Sodium chlorid.	Ferric acetate powdered.									
	C. c.	*C. c.*	*C. c.*	*Grams.*	*Grams.*	Sample—								
20	500	None.	500	180	None.	No. 20......... +9.2	9.4	9.0	9.0	8.9	9.1	9.2	9.2	9.2
21	500	500	None.	180	None.	No. 21......... 9.4	9.6	9.2	9.1	9.0	9.0	9.0	9.1	9.0
22	500	None.	500	180	[1]4	No. 22......... 9.4	9.4	9.5	9.4	9.3	9.3	9.3	9.2	9.3
23	500	500	None.	180	4	No. 23......... 8.4	6.3	6.2	2.7	2.3	5.9	4.0	3.1	2.9

[1] Equivalent to 1 gram Fe per liter.

NOTE.—Readings on Ventzke scale, divided by 4, give per cent of lactose in mixture.

Lōb and Pulvermacher's observation (p. 56) that dextrose is much more easily oxidized than sucrose, and that the sucrose apparently can oxidize only as fast as it is first inverted, suggests the desirability of further experiment along the lines of the work on sample No. 25, but in which the sample is soured before being used in the experiment. In the presence of lactic acid (or its combination with casein) it is very probable that the lactose present would be inverted, even if very slowly. Then the iron and oxygen would have the entire storage period of several months to bring about the slight chemical changes presumably sufficient to give butter an "off flavor."

ODORS PRODUCED IN MILK BY THE ADDITION OF IRON SALTS.

In our experiments the production of substances having a disagreeable odor and taste was the most important part of the work. No chemical change, however pronounced, that presumably did not affect the flavor of butter was of more than incidental interest. For this reason the odor of the experimental material was always carefully noted.

It was stated before (p. 60) that on adding ferrous sulfate to milk containing salt, a very strong, nauseating odor was produced. This observation had been made before in mixtures of milk, hydrogen peroxid and ferric chlorid, but the odor was not produced every time that ferric chlorid and hydrogen peroxid were added to milk. It was obviously desirable to know whether iron salts could produce undesirable odors in milk and whether the experimental conditions under which such odors were produced were in any way similar to the conditions in cold storage butter.

After several trials it was found that ferrous salts added to milk in the proportion of 1 part of metallic iron to 1,000 parts of milk would result in the production of a very powerful odor. The method of the experiment was very simple as the following example shows:

Several liters of raw milk as obtained fresh from the dealer were separated. Sodium chlorid was added to the skim milk, anywhere from 18 per cent to saturation, or the sodium chlorid may be omitted altogether. The sodium chlorid serves both as a preservative and as a normal constituent of butter curd solution. Skim milk was used because by eliminating the fat and fat soluble substances the substances causing the odor could be better determined. The sample of salted skim milk could be used at once or after several days' standing at room temperature. Portions of 300 cubic centimeters each were transferred to 1-liter Erlenmeyer flasks. To each flask there was then added a calculated quantity of the metal salt. The following salts were used in the several experiments; some of them were used very many times: Ferrous sulfate, ferrous ammonium sulfate, ferrous lactate, ferric acetate, ferric chlorid, and to a lesser extent some salts of the following metals: Copper, manganese, aluminium, and lead.

In no case was any odor produced by any metal salt other than iron. Ferrous salts almost always, ferric salts very seldom, produced an odor in the milk. The quantities used were calculated to make 1 part of metal present in 1,000 parts of milk. When this quantity of a ferrous salt is used the odor becomes very powerful in a few minutes. However, 1 part of ferrous iron in 50,000 parts of milk could easily be shown to produce an odor plainly perceptible by several persons to whom no information had been previously given regarding the nature of the samples to be smelled. The odor develops slowly when the amount of iron is small. For 1 part of iron to 50,000 of milk an hour should be allowed.

It seems that the odor is developed at that time when the color of the mixture changes to the more highly colored ferric salt.

Although the odor strongly suggests putrefying protein or hydrogen sulfid, tests made for hydrogen sulfid were negative. The tests were made by passing a current of air through milk in which an odor had been developed by the addition of ferrous iron, and then through an alkaline solution of lead acetate.

It is doubtful whether the odor came from the fat, because skim milk was used, and it was doubtful whether lactose was the cause. It seemed probable that protein was being acted upon by the iron. In one experiment in which solutions of egg-white and of egg-yolk were used the same results were obtained as before, i. e., the addition of iron salts (ferrous sulfate and ferric chlorid) resulted in the production of a strong odor. Whether protein was acted upon in the experiments or not, is difficult to say.

On looking through the literature on the oxidation of proteins, very little was found that would throw light on the oxidation of protein by means of comparatively mild oxidizing agents. In most of the researches the protein was broken down completely by the reagents used, and the work was done for the purpose of studying either the products of the oxidation or the various oxidation stages through which the protein goes during the course of metabolism. No records were found in which the protein oxidation was studied for the particular purpose of observing whether odoriferous substances were formed. The oxidation of protein in storage butter (if it occurs at all) is probably very mild. There seems to be no apparent change in the quantity of protein in butter before and after storage.

However, two researches were found in the literature which were highly instructive.

Neuberg and Blumenthal[1] studied the oxidation products of gelatin, using ferrous sulfate and hydrogen peroxid. In the distillates from 2 kilograms of gelatin they isolated and identified isovaleraldehyde. Other volatile products were also formed. Orgler[2] repeated some of the work of Neuberg and Blumenthal, using crystallized egg albumin, copper sulfate, and hydrogen peroxid. Acetone was detected and identified in the distillates from such a mixture, which distillate, according to Orgler, had a strong fruity odor.

It follows that if the ferrous salts used in the production of an odor in milk act on some milk protein with the formation of aldehyde or ketone substances, it ought to be possible to take milk (containing salt), add a ferrous salt, and obtain from it by distillation some of the substances mentioned by Neuberg and Blumenthal and by Orgler. Two experiments were made which, while not so conclusive as to make further experiment unnecessary, gave results so much in accord with expectations that there is little doubt but what the ferrous sulfate used in the experiments caused the formation of substances which gave the iodoform test. Beyond this their chemical nature was not investigated.

THE PRODUCTION OF IODOFORM-REACTING SUBSTANCES IN MILK BY FERROUS IRON.

To an ordinary 2-liter side-arm distillation flask 1 liter of fresh skim milk was transferred (sample 42.2). The sample contained 200 grams of sodium chlorid to 1 liter of skim milk. It was quickly brought to a boil and 10 cubic centimeters distilled over. This was tested with sodium hydroxid solution (1:3) and iodin solution without heating for substances giving the iodoform test.[3]

The test was positive. The above procedure was repeated on some of the same sample of milk under the same conditions, except that 5 grams of the crystallized ferrous sulfate (Fe 1 : 1 000) was added just before distilling. The distillate gave a much stronger iodoform test; that is, there was a very appreciable immediate precipitate of iodoform. A second sample of skim milk was distilled as before. This sample (No. 37x) was obtained from the same dealer as the previous sample (sample 42), and after being skimmed they probably did not differ very materially in their composition. At the time of the experiment this sample (37x) was raw skim milk containing 30 per cent of sodium chlorid (300 grams of salt to 1 liter of milk) and 1 part of iron as ferrous sulfate to 5 000 parts of milk.

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[1] Neuberg, C., and Blumenthal, F. Über die Bildung von Isovaleraldehyd und Aceton aus Gelatine. Beiträge zur Chemischen Physiologie und Pathologie, vol. 2, no. 5–6, pp. 238–250. Braunschweig, May, 1902.

[2] Orgler, Arnold. Über die Entstehung von Aceton aus krystallisiertem Oralbumin. Beiträge zur Chemischen Physiologie und Pathologie, vol. 1, no. 10–12, pp. 583. Braunschweig, January, 1902.

[3] Mulliken, Samuel Parsons. Identification of Pure Organic Compounds. See vol. 1, p. 166.

The salt and iron were added on the same day the sample was received. After remaining at room temperature in the laboratory for 12 days, during which time several liters were used for other purposes, 3 liters of this sample were transferred to a 7-liter bottle and oxygen was blown through it slowly for 4 days (96 hours). One liter of this was distilled. The distillate (10 c. c.) yielded more iodoform than either of the other two. Judging by inspection, on distilling fresh skim milk a very small but distinctly perceptible quantity of iodoform-reacting substance was obtained; fresh skim milk and iron yielded more, and skim milk and iron first saturated with oxygen yielded most. There could be little doubt about the relative amounts of iodoform, but the experiment was repeated on portions of the same samples as before for the purpose of estimating quantitatively the iodoform obtained.

Each distillation was continued until six 10 cubic centimeter portions of distillate were obtained. Iodoform tests on these were made by adding to each portion contained in a test tube 10 drops of sodium hydroxid solution (1 : 3) and sufficient iodin solution to insure a slight excess. In every case precipitates of iodoform were obtained almost immediately and without the aid of heat. Very little iodoform, if any, was obtained in the last 10 cubic centimeters of distillate.

The iodoform was washed first by decantation, then transferred to filter papers and washed till the filtrates gave only a very faint cloud with silver nitrate solution. Some of the iodoform was, of course, lost through solution in the wash water, but the relative amounts in this case rather than the absolute were just as desirable. The amount lost in this way probably was small compared with the amounts present. The blank determination (No. 42.3) was lost. It contained a distinctly perceptible precipitate, but too small in amount to compare with either of the other two. For the estimation of the iodoform a method given in the Pharmaceutical Journal, page 555, volume 82, 1909, was used. The iodoform on the filter papers was dissolved in alcohol and ether and the solutions received in 300 cubic centimeter Erlenmeyer flasks. To these flasks and to controls 1 cubic centimeter nitrous acid (fuming nitric acid) and 50 cubic centimeters approximately tenth normal silver nitrate solution were added. The mixtures were heated on the steam bath over night. The silver still remaining in solution was estimated with standard ammonium sulfocyanid solution, using ferric ammonium sulfate as indicator.

The distillate from the fresh milk containing ferrous sulfate (No. 42.4, Fe 1 : 1,000) yielded 15.4 milligrams of iodoform; the distillate from the 12 days' old milk containing ferrous sulfate (No. 37x, Fe 1 : 5 000) and saturated with oxygen gave 54.7 milligrams of iodoform.

These amounts of iodoform correspond in the titrations to 1.37 cubic centimeters in the first and to 4.88 cubic centimeters of silver nitrate solution (N/11.7) in the second determination.

While these results do not prove that the iodoform was obtained from oxidation products of milk protein, they do prove the possibility of such oxidation. By distilling such mixtures under low pressure and at low temperature to remove the possible objection that the temperature of distillation is not the temperature at which chemical changes take place in storage butter, the identity of the iodoform-reacting substances could without doubt be ascertained.

Whether the small amounts of iron ordinarily present in butter (see p. 54) can slowly bring about the same kind of a change that larger amounts of iron bring about in milk in a very much shorter time is to be determined by future investigation.

SUMMARY.

The failure of previous investigators to find evidences of proteolysis in cold-storage butter may have been due to difficulty in obtaining proper precipitations in the curd solution.

Methods of analysis have been perfected which permit the use of large samples and show the first stages in the proteolysis. This method gave no evidence of an increase in soluble nitrogen in butter on long standing at 0° F., even when the conditions of the manufacture were most favorable to such changes.

Buttermilk from sweet unpasteurized cream and from sweet pasteurized cream when preserved with 18 per cent sodium chlorid to correspond to butter-curd solution showed no proteolysis during a long period in cold storage.

Bacterial enzym held in cold storage in milk containing 18 per cent of sodium chlorid gave some evidence of proteolysis. The action of pepsin and trypsin under similar conditions was not completely inhibited.

Butter made from sweet pasteurized cream keeps much better than butter made from similar cream without pasteurization, but the changes in the unpasteurized cream butter can not be reproduced by reinoculating the pasteurized cream with the bacteria of the cream before pasteurization.

By means of specially designed apparatus exact analysis was made of the gases contained in butter. About 10 per cent, by volume, of fresh butter is gas consisting approximately of nitrogen (by difference) 33 per cent, oxygen 20 per cent, and the remainder of gases absorbable by sodium hydroxid. The oxygen was materially less after storage.

The addition of iron to the cream even in as small an amount as one or two parts per million parts of cream has an influence on the flavor of the butter. This work gives nothing to show that the nature of the flavor is appreciably changed, but the rate of development is accelerated.

The cream may take up iron in quantities sufficient to affect the flavor from rusty cans or even from the exposed boltheads or other metal parts of the churn.

The action of copper is similar but perhaps more intense.

It was found that in milk to which 18 per cent sodium chlorid had been added there was no change in the lactose when iron was added and a current of oxygen passed through the milk for 72 hours.

A strong odor may be produced in milk by the addition of small amounts of iron salts. The ferrous salts are more active than the ferric salts.

The iodoform test is much stronger in distillates from milk containing ferrous sulfate.

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U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ANIMAL INDUSTRY.—BULLETIN 163.
A. D. MELVIN, CHIEF OF BUREAU.

THE LIFE HISTORY OF HABRONEMA MUSCÆ (CARTER), A PARASITE OF THE HORSE TRANSMITTED BY THE HOUSE FLY.

BY

B. H. RANSOM, PH. D.,
Chief of the Zoological Division.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1913.

LETTER OF TRANSMITTAL.

United States Department of Agriculture,
Bureau of Animal Industry,
Washington, D. C., October 7, 1912.

Sir: I have the honor to transmit herewith for publication in the bulletin series of this bureau a manuscript entitled "The Life History of *Habronema muscæ* (Carter), a Parasite of the Horse Transmitted by the House Fly," by Dr. B. H. Ransom, Chief of the Zoological Division.

Respectfully,

A. D. Melvin,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

ADDITIONAL COPIES of this publication may be procured from the SUPERINTENDENT OF DOCUMENTS, Government Printing Office, Washington, D. C., at 10 cents per copy

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THE LIFE HISTORY OF HABRONEMA MUSCÆ (CARTER), A PARASITE OF THE HORSE TRANSMITTED BY THE HOUSE FLY.

SUMMARY.

Over 50 years ago in Bombay, India, the late H. J. Carter discovered some larval nematode worms in the common house fly. These worms, known as *Habronema muscæ*, have since been repeatedly observed in flies in various parts of the world, but their life history remained a mystery which has only recently been cleared up through investigations made by the present writer. The results of these investigations show that the adult stage of the parasite occurs in the stomach of horses. The embryos produced by the parent worms in the stomach leave the body in the alimentary dejecta and enter the bodies of fly larvæ which have hatched from eggs deposited in the dejecta by house flies. The young worms grow and develop in the fly larvæ and reach their final stage of larval development at about the time the flies emerge in the winged state from the pupal stage. Finally they complete their development to maturity after the flies which they infest are swallowed by horses. In flies the parasites are commonly found in the head, frequently in the proboscis, but they occur also in the thorax and abdomen. The occurrence of these worms in a fly is positive proof that the fly was bred in horse manure, hence the frequency with which they are found in flies roughly indicates the extent to which horse manure in the neighborhood is serving as a breeding place for flies. The adult *Habronema muscæ* is very similar to *Spiroptera microstoma*, known since 1866 as a parasite occurring in the stomach of the horse, but is distinctly a different species. The two species, however, are congeneric, and the latter accordingly takes the name *Habronema microstoma*.

INTRODUCTION.

In a prior paper (Ransom, 1911) I have briefly reported some investigations which led to the discovery that *Habronema muscæ* (Carter), known since 1861 as a parasite of the house fly, is the larval stage of a parasite of the horse, closely related to *Spiroptera microstoma* (Schneider, 1866). These investigations indicate that the embryos of the parasite leave the body of the definitive host in the feces, enter the bodies of fly larvæ, reach their final larval stage shortly before or after the transformation of the flies into the imaginal state, and at last complete their development to maturity when the flies which

(Carter), known since 1861 as a parasite of the house fly, is the larval

they infest are swallowed by horses. The life history of *Habronema muscæ* is thus of the type, not unusual, that involves a simple alternation between two hosts, one a vertebrate harboring the adult stage of the parasite, and the other an invertebrate harboring the larval stage.

HISTORICAL.

The first definite record of *Habronema muscæ* is that of Carter (1861), who found two nematode worms in the head of a house fly at Bombay, India, in November, 1859. In July, 1860, the same author made further examinations of flies at Bombay and found that on an average every third fly contained from 2 to 20 worms, located chiefly in the proboscis, but occasionally among the soft tissues of the head and posterior part of the abdomen. Carter erroneously considered these worms to be bisexual and mature. He gave them the name *Filaria muscæ*, and described them as follows:

> Linear, cylindrical, faintly striated transversely, gradually diminishing toward the head, which is obtuse and furnished with four papillæ at a little distance from the mouth, two above and two below; diminishing also toward the tail, which is short, and terminated by a dilated round extremity covered with short spines. Mouth in the center of the anterior extremity. Anal orifice at the root of the tail.
>
> Oesophagus commencing from a slightly dilated oral orifice, narrow at first, then becoming suddenly increased in caliber, and, after extending some distance backwards, joining the intestine, apparently without any line of demarcation, opposite the anterior termination of the hepatic organ. Intestine continued straight through the body, and nearly of the same size, on to the rectum, which is short and obliquely directed towards the anus. Oesophageal sheath [fig. 2] commencing at the termination of the narrow portion of the

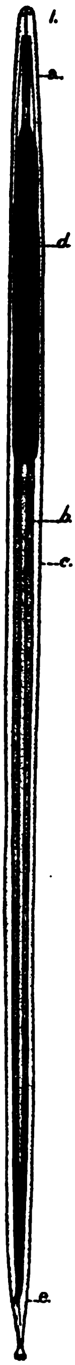

FIG. 1.—*Habronema muscæ* from house fly. *a*, esophagus; *b*, intestine; *c*, "intestinal sheath;" *d*, "liver;" *e*, rectum and anus. Enlarged. After Carter, 1861 *b*, pl. 1 A, fig. 2. Erroneous interpretations of Carter indicated by quotation marks.

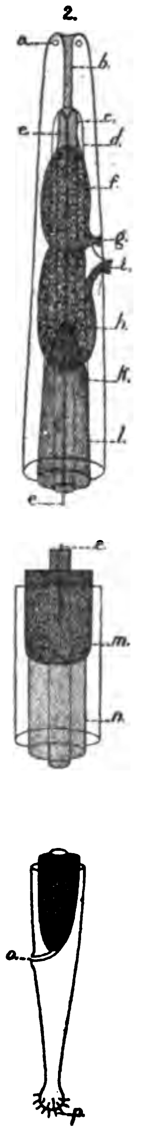

FIG. 2.—*Habronema muscæ* from house fly. *a*, head papillæ; *b*, "small part of esophagus;" *c*, large ditto; *d*, "esophageal sheath;" *e*, *e*, *e*, "dorsal vessel;" *f*, "ovary charged with nucleated cells;" *g*, "vulva;" *h*, "testicle charged with nucleated cells;" *i*, "penis;" *k*, "anterior extremity;" *l*, "anterior extremity of intestine;" *m*, "posterior end of liver;" *n*, intestine and "intestinal sheath;" *o*, rectum and anus; *p*, spinous extremity of tail. More highly magnified than fig. 1. After Carter, 1861 *b*, pl. 1 A, fig. 3. Erroneous interpretations of Carter indicated by quotation marks.

> oesophagus posteriorly, where the latter is embraced by the dorsal vessel, gradually increasing backwards to join, without a line of demarcation, the sheath of the intestine, which, on its part, soon attaining its maximum caliber, is continued backwards, of the same size, to the termination of the hepatic organ, where it becomes slightly but suddenly reduced in diameter and afterwards maintains nearly the same size on to the rectum.
>
> Hepatic organ [fig. 1, *d*] marked by a dense white layer of oil globules and granular matter wthin the intestinal sheath, surrounding the anterior third of the intestine, commencing opposite the union of the latter with the oesophagus, and terminating at the sudden diminution in diameter of the intestinal sheath, where it is defined by a circular line (*m*). Rectum (*o*) more or less obscured by muscular and other structure, in the midst of which two glandular bodies are observed opposite its junction with the intestine. Dorsal vessel (*e e c*) extending from the point of union between the smaller and larger portions of the oesophagus (*e*), which it embraces by bifurcation, to the posterior end of the hepatic organ (*m*), where it again appears to bifurcate and to embrace the intestinal sheath.
>
> Generative organs situated in the anterior part of the body, under the oesophagus and anterior part of the intestine, consisting of an ovary [fig. 2, *f*] and testicle (*h*), opening on the right side, a little in front of the liver, by separate ducts about one-hundredth of an inch apart, the former, which is anterior, by a simple papillary aperture (*g*), and the latter by the same, but with a short funnel-shaped exsertile organ (*i*). Ovary unseen in detail, but charged with nucleated cells, and presenting a distinct line of demarcation between itself and the testicle, which on its part appears to be saccular, and also contains nucleated cells that are sometimes spermatophorous. Spermatozoa indistinctly seen; single, in cells about 1-700th of an inch in diameter; consisting, when half developed, of a striated, pyramidal or triangular body growing out of a small mass of granular mucus on one side of the cell; when fully developed apparently club-shaped.
>
> *Size.* About 1-11th of an inch long and 1-313th of an inch in its broadest diameter—that is, in the middle.
>
> *Hab.* Proboscis, head, and posterior part of the abdomen of the common house fly (*Musca domestica*).
>
> *Loc.* Island of Bombay.

In some of its details Carter's description is rather faulty, and some of the interpretations placed on observed structures are quite wrong. For example, the "narrow portion" of the esophagus is the pharynx, and the "hepatic organ" is part of the esophagus and not a structure surrounding the anterior third of the intestine. The "dorsal vessel" is apparently one of the lateral lines, or perhaps the lumen of the esophagus. The "ovary" and "testicle" are misinterpretations of a mass of cells located in the anterior esophageal region, probably belonging to the nervous system. The genital ducts and pores described by Carter are apparently misinterpretations of the excretory pore and canals.

Among the observations Carter notes that he has not seen the ova in their fully developed state, and that he is—

> ignorant of the future of this worm; but knowing that many Entozoa are nursed in one animal and lay their eggs in another, it is not improbable that

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mouth showed 3 slight swellings, with two small papillæ on each. The esophagus consisted of an anterior short portion [pharynx], 0.05 mm. long, which was enlarged at the mouth to form a funnel-shaped vestibulum, and a posterior portion, about twice as thick as the anterior portion, with a very muscular wall supplied with numerous small nuclei. The esophagus was relatively long, eleven-sixteenths the length of the body. The intestine was yellowish in color, thinner than the esophagus, and composed of polygonal cells. The anus was 0.07 mm. from the tip of the tail. The posterior end of the intestine was supplied with prominent cylindrical granular gland cells. The tail was gradually attenuated and the tip supplied with very fine rounded spines or papillæ arranged very close together.

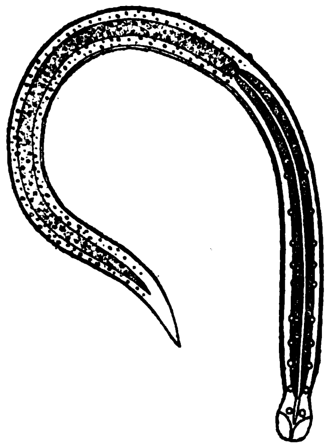

FIG. 3.—*Filaria stomoxeos* (embryo) from stable fly (*Stomoxys calcitrans*). Enlarged. After Linstow, 1875 *a*, pl. 3, fig. 22.

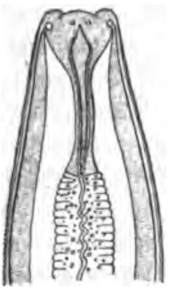

FIG. 4. — *Filaria stomoxeos* (larva). Anterior end. Enlarged. After Linstow, 1875 *a*, pl. 3, fig. 20.

Linstow at first believed that he had specimens of *Habronema muscæ*, but in view of the fact that the worms from *Stomoxys* were without sexual organs, had six oral papillæ, and lacked the globular swelling on the tip of the tail, whereas *H. muscæ* as described by Carter was sexually mature, had 4 oral papillæ, and had a spiny globular swelling on the tip of the tail, Linstow concluded that the form from *Stomoxys* was a different species and called it *Filaria stomoxeos*. Although Linstow considered the embryo which he found in *Stomoxys* to be of the same species as the larvæ, this is by no means certain. Noè (1903 *a*, p. 392) states that the *Filaria stomoxeos* of Linstow is the same as the nematodes found by him in *Stomoxys*, which he considered to be intermediate stages of *Filaria labiato-papillosa* of cattle. Noè's statements have been commonly accepted, but as a matter of fact it is impossible to judge definitely from the data given whether or not he is correct in his opinion as to the identity of the nematodes and as to their being intermediate stages of *Filaria labiato-papillosa*. From Linstow's description, however, it would appear that *Filaria stomoxeos* closely

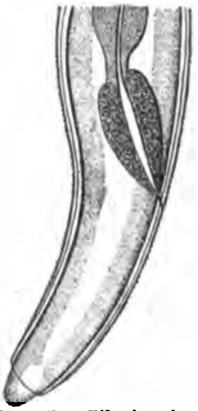

FIG. 5.—*Filaria stomoxeos* (larva). Posterior end. Enlarged. After Linstow, 1875 *a*, pl. 3, fig. 21.

resembles *Habronema muscæ*, and one would be inclined to consider it a species of *Habronema* rather than the larva of *Filaria labiato-papillosa.* The possibility is not excluded that *Filaria stomoxeos* is the larval stage of *Habronema microstoma* (Schneider, 1866).

Bartram (1880 *a*) noted the occurrence of small worms resembling vinegar-eels in the heads of house flies and wrote to the editor of the American Journal of Microscopy inquiring as to their identity.

Generali (1886 *d*), at Modena, Italy, noted the occurrence of nematodes in house flies, stating that he has not succeeded in finding them in other species. The frequency of occurrence, based on an examination of 250 flies during the summer of 1884, was 12.6 per cent. Ordinarily he found but one, rarely two, in the same fly; once he found three, and once four. The parasites were located in the head. They appeared to be larval stages. The size given was 1 to 1.5 mm. in length and 40 to 50 µ in width. They are extraordinarily active when removed from the fly. In salt solution (1 to 1,000) they continue very active during the first 24 hours; during the following day their movements become slower; on the third day they move slowly; on the fourth day their movements practically cease. A larva from which the water in which it was immersed had evaporated became motionless, but five or six minutes after the addition of more water resumed its movements, which continued for several hours. Generali states that it is conceivable that the parasites during their embryonic stage penetrate into the fly, but that he had found only the one stage of development.

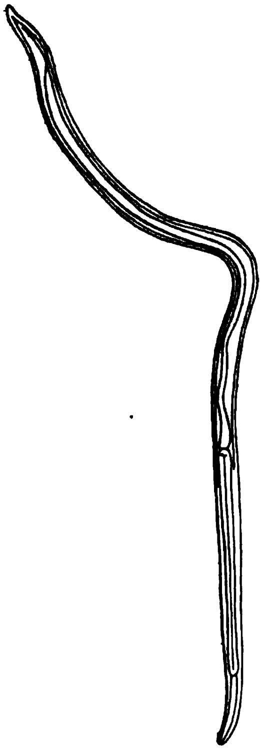

FIG. 6.—*Habronema muscæ* from fly. ×44. After Piana, 1897 *a*, fig. 15.

Presumably the nematodes found by Generali were *Habronema muscæ*, although the final larval stage of this species is much longer than 1 to 1.5 mm., the figures given by Generali. This discrepancy, however, is probably the result of an error in measurement and is insufficient to justify one in concluding that Generali's nematodes were not *Habronema muscæ.*

Piana (1897*a*) in connection with a study of *Dispharagus nasutus* was led to examine nematodes found in the heads of flies in order to determine whether they might not represent larval stages of the *Dispharagus.* The fly nematodes (figs. 6–8), he remarks, may be found by preparing the proboscis of the common fly in water under the microscope, but it is not always easy to find them. He notes that in certain localities and at certain stages of the fly's life the flies harboring nematode larvæ in the proboscis are, to say the least, very rare, but that in other localities and at other stages infested flies are found at the rate of 20 to 30 per cent. He observed that when the larvæ are freed from the fly's proboscis they begin to swim so rapidly in a serpentine manner that it is impossible to make out anatomical details. By poisoning them with nicotine he rendered them motionless without sensibly altering their structure. A larva thus narcotized measured 2.68 mm. long and 0.08 mm. broad. The form was cylindrical, tapering gradually toward the extremity. Width, at a distance of 0.036 mm. from the mouth, 0.036 mm.; width in the anal region 0.031 mm.; anus 0.10 mm. from the tip of the tail. Tip of the tail blunt, with a transverse diameter of about 0.010 mm. The two buccal lips found in *Dispharagus nasutus* are absent. The digestive tract presents the same divisions as that of *D. nasutus;* but at the point of union of the second and third sections there is a slight dilatation of the lumen not seen in *Dispharagus.* The tail, although very similar to that of *Dispharagus nasutus*, has a relatively larger apex, and a terminal surface covered with minute chitinous points. In view of the difference between the nematodes of the fly and young stages of *Dispharagus nasutus* from chickens, Piana concluded that the two were not related. Piana observes that the nematodes which he found in flies in their general conformation and in the structure of the caudal end of the body are very similar to those described by Carter. Considering the similarity between the nematodes found by Piana as described and figured by him and *Habronema muscæ* as described and figured by Carter, and considering also the fact that they were found in the same host it is fair to assume that they are the same species, just as I have assumed that the nematodes which I have found in flies belong to Carter's species.

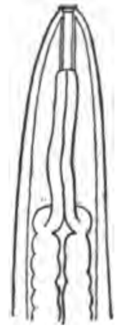
FIG. 7.—*Habronema muscæ* from fly. Anterior end. × 220. After Piana, 1897 *a*, fig. 16.

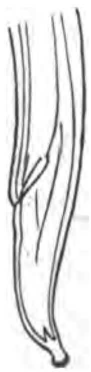
FIG. 8.—*Habronema muscæ* from fly. Posterior end. × 220. After Piana, 1897 *a*, fig. 17.

AUTHOR'S OBSERVATIONS.

FREQUENCY OF LARVÆ IN FLIES.

ADULT FLIES.

One hundred and thirty-seven flies, of which a statistical record was kept, have been examined by the present writer for the presence

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LARVÆ.

One hundred and seventy larvæ were examined, 28 of which may have been of some species other than the house fly, and of 13 of which in an experiment had fed only on boiled horse manure. Of these 170 larvæ only 1 was found to be infested. This small number of infested larvæ found is explained by the fact that it is extremely difficult to discover the young stages of the parasite, a difficulty which is greatly aggravated by the common occurrence of numerous small nematodes of several species on the surface of the body and more rarely in the alimentary tract of fly larvæ.

NUMBER OF LARVAL WORMS IN INDIVIDUAL FLIES.

ADULT FLIES.

Carter noted as many as 20 worms in one fly. The most which I have found is 8. Out of 43 flies of which a record as to the number of parasites was kept 25 had but 1 parasite, 6 had 2 parasites, 6 had 3 parasites, 3 had 4 parasites, 2 had 5 parasites, and 1 had 8 parasites.

PUPÆ.

In 23 infested pupæ 1 worm was found in 15, 2 worms in 5, 3 in 1, 4 in 1, and 5 in 1.

LARVÆ.

In 1 larva a single encysted worm was found.

LOCATION IN THE BODY.

ADULT FLIES.

A record was made of the location of the parasites in the case of 37 flies. In 17 cases the head was infested, in 8 cases the thorax, and in 19 cases the abdomen. In 12 cases the head only was infested, in 4 cases the thorax only, and in 15 cases the abdomen only. Simultaneous infestation of the head and thorax occurred in 2 cases, of the head and abdomen in 1 case, of the thorax and abdomen in 2 cases, and of the head, thorax, and abdomen in 1 case. The number of worms in the head was 1 in 11 cases, 2 in 1 case, 3 in 1 case, 4 in 2 cases, 5 in 1 case, and 6 in 1 case. The number in the thorax was 1 in 5 cases and 2 in 3 cases. The number in the abdomen was 1 in 11 cases, 2 in 4 cases, 3 in 3 cases, and 5 in 1 case. Encysted larvæ were found in the abdomen in 6 flies, in 5 of which no worms were present in either the head or thorax; in the remaining fly there were larvæ in both the head and the thorax. All of the flies in which encysted larvæ were found were flies which had recently emerged. In 4 of the cases in which the head was infested it was noted that larvæ were present in the proboscis, 5 in 1, 4 in another, and 1 in the remaining 2 cases.

PUPÆ.

The distribution in the case of 9 pupæ in which the location was recorded was as follows:

Abdomen infested 9 times, head once, thorax once. Simultaneous infestation of the head and abdomen and of the head and thorax occurred once each. Encysted worms were found in 11 out of 23 infested pupæ, and in all cases in which the location was recorded these were located in the abdomen.

EXPERIMENTS WITH LARVÆ REMOVED FROM FLIES.

In August, 1909, 10 *Habronema* larvæ taken from flies caught in the laboratory of the Zoological Division of the Bureau of Animal Industry at Washington, D. C., were placed in a culture medium composed of water and horse feces which had been sterilized by boiling. Two days later the worms were all quiescent and apparently dead. June 10, 1910, 5 larvæ from the proboscis of a fly were placed in tap water. The following day 4 of them were still alive, but all were dead a day or two later. June 13, 1910, larvæ from dead flies were placed in a dish containing water and the remains of the dead flies. These larvæ were still alive on the following day, but succumbed within two days. Two larvæ placed in a moist cell with horse feces, June 22, 1910, died within a few days. A few other similar experiments were carried out, the details of which can not be given, as the notes on them have been lost. In every case, however, the worms died within a very few days without undergoing any further development. The longest period of survival noted was between 5 and 8 days, in the case of a larva removed from a fly January 3, 1912, and placed in physiological salt solution. The worm was still alive January 8, but was dead January 11. From these experiments it appears that the larvæ are able to exist for only a limited period when removed from their host, thus confirming the results of the experiments made by Carter, who found that the worms lived but a few hours in culture media of water, sugar and water, sugar and water with gum acacia added, and sugar and water with gelatinized *Nostoc* added. As no indications of any further development of the worms were noted in any of the experiments, attempts to grow the worms in cultures were abandoned early in the investigations.

SURVIVAL OF LARVÆ IN DEAD FLIES.

Three flies which died June 10 or 11, 1910, were examined June 13 and found to contain living larvæ. It is thus evident that the worms may survive in flies at least two days after the death of their host.

Dead flies were not noticed in the stomachs of two horses examined at Omaha in September, 1911, but in one of them several fly pupæ were observed. If horses swallow fly pupæ, the chances of their swallowing dead flies seem equally good, and hence it seems quite certain that dead infested flies are an occasional, perhaps a common, source of infection.

ESCAPE OF LARVÆ FROM FLIES.

June 14, 1910, an active larva was observed in the moisture in the bottom of a jar in which some flies had been confined since the day before. Many of the flies were dead, and it is therefore uncertain whether the worm escaped before or after the death of its host, and it is also uncertain whether the host fly had not been injured in such a way as to provide an exit for the worm.

The escape of larvæ from flies into water or into moist material liable to be ingested by horses is a possible mode by which infection of the final host may occur, but the fact that the worms, so far as observed, are unable to live more than a few days outside the body of a host goes to prove that this is not a normal occurrence in their life history.

The fact that the proboscis is a favorite location of the larval worms suggests that they may abandon their intermediate host in some such manner as *Filaria* larvæ abandon the mosquito. It is conceivable that they might escape through a slight rupture of the proboscis occurring at a moment when the fly was sucking moisture from the mucous membrane of a horse's lips, after which they could readily reach their final location, the stomach. As yet, however, no evidence of such an occurrence has been obtained.

DEVELOPMENT.

EMBRYOS.

The eggs of *Habronema muscæ* as seen in the uterus of the gravid female, in the earliest stage of development are elongated with very thin shells, 40 to 50µ long by 10 to 12µ wide. With the progress of development of the embryo they become longer. At a stage shown in figure 9, *e*, in which the embryo is doubled on itself head to tail, the egg measures 80µ in length by nearly 12µ in width, and at a little later stage (fig. 9, *f*) in which the embryo has straightened out, becoming also shorter, the eggshell measures 87µ in length and of about the same width as before. Later the shell becomes rather closely applied to the body of the embryo except on one side in the posterior region where it is held away by the curving tail. The embryo (fig. 9, *g*, *h*, *i*) now measures 85 to 100µ in length by 5 to 7µ in width. The anterior end is rounded. The thickness of the body is nearly uniform, except that it begins to taper in the posterior third, terminating in a pointed tail which curves forward and holds the shell or sheath of the worm away from the body as already noted. A small nucleus is rather conspicuous, located 35 to 40µ from the anterior end, and another one is quite commonly to be seen about 15µ from the tip of the tail. The contents of the body are finely granular. The alimentary canal has not been made out.

The embryos are active and motile when alive. Undoubtedly they pass out of the body of the horse in the feces. Whether they undergo further development before entering fly larvæ has not been determined, nor has it been determined whether they forcibly enter the intermediate host or whether they are passively swallowed. The latter seems the more plausible.

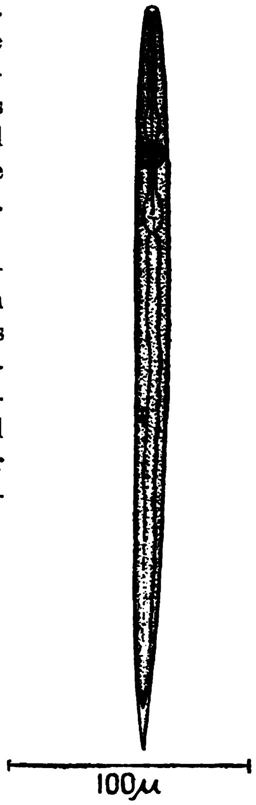

FIG. 10.—Rhabditiform nematode embryo (*? Habronema muscæ*) from fly larva. × 320. Original.

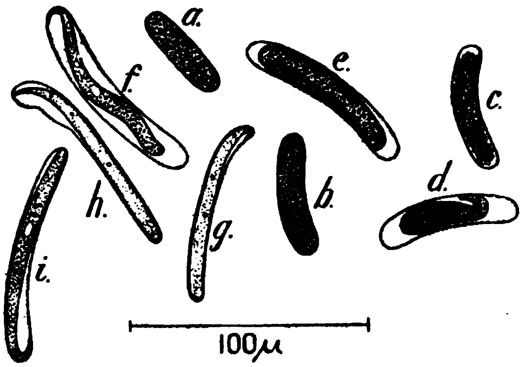

FIG. 9.—Eggs and embryos of *Habronema muscæ*. × 310. Original.

Embryonic stages definitely recognized as belonging to *Habronema muscæ* have not been found in fly larvæ. A rhabditiform embryo was found August 23, 1911, in a fly larva from a culture of horse feces collected August 9. This embryo (fig. 10), in process of molting, measured 275µ in length by 13µ in width. The slender cylindrical pharynx was 15µ long. The esophagus, 75µ long, had a toothed posterior bulb, and an enlargement just in front of the middle. Just behind this enlargement there was a conspicuous nerve ring. The genital primordium was 160µ from the anterior end. It is possible that this was an embryo of *Habronema*, but this has not been proved. The common occurrence of nematode embryos, and of small free living adult nematodes as well, on the exterior surface of the body of fly larvæ renders a search for internal parasites very difficult, in view of the fact that one can not always be sure that nematodes found in dissecting the larvæ did not come from the exterior of the body. To a certain extent there is a similar difficulty in the case of pupæ and adult flies, but here the fact that the parasites have already developed to a considerable size enables one to distinguish them from the small embryos which come from the exterior.

LARVÆ.

Stage 1.—The earliest stage in flies known definitely to belong to *Habronema* was first found in a pupa from a culture of horse feces collected in a fresh state from the streets of Colorado Springs, August 9, 1911. The pupa was examined August 22, and hence was not over 2 weeks old. The parasite (fig. 11) measured about 450μ in length by 45μ in width. It had a shallow pharnyx or mouth cavity, followed by a simple esophagus 160μ long, which increased from a width of less than 10μ anteriorly to a width of 20μ at its posterior end. At a distance of about 70μ from the anterior end of the body the esophagus was surrounded by a nerve ring. The intestine at first exhibiting an enlargement 30μ in diameter, soon diminished to a diameter of 20 to 25μ, a size approximately maintained until it joined the almost spherical or pyriform rectum, which measured about 30μ in diameter. The wall of the rectum exhibited a sort of foam structure. The anal opening was closed, and a rounded projection occurred at this point. The body at the anus measured about 40μ in thickness, and tapered suddenly to the blunt tip of the tail, which was about 40μ from the anus. Comparatively large, prominent nuclei were distributed throughout the body, in the esophagus, intestine, and body wall.

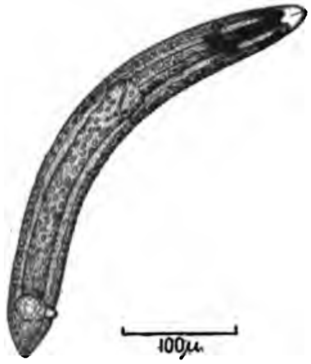

FIG. 11.—*Habronema muscæ*. Larva (Stage 1) from fly pupa. × 150. Original.

The larva was in process of molting or about to molt, and the old cuticle separated somewhat from the body was visible at the anterior end.

Later, that is, on August 26, a nematode in the same stage of development, and of the same structure, about 400μ long by 40μ thick, with an esophagus about 140μ long, was found in a fly larva from the same culture. This nematode was contained in a thin-walled spherical cyst, and it is probable that the worm found in the pupa was also encysted.

Stage 2.—The development from stage 1 into the next stage consists principally in an increase in length without much change in width and in a slight change in the structure of the oral end. The stage designated as No. 2 is shown in figure 12. The worm here figured was found in the abdomen of a pupa, August 26, which had developed in a culture of horse feces collected August 9. This worm was inclosed in a thin-walled cyst. As in the preceding stage, numerous small nuclei are conspicuous in the body wall and alimentary tract. The length of this worm is nearly 1 mm. and the maximum width about 50μ. The esophagus instead of immediately following the small oral cavity is now separated from it by a very slender pharynx about 12μ long. A clear space surrounds the pharynx, and extends to the body wall. The esophagus has the same structure as in the preceding stage but is longer, its base being about 300μ from the anterior end of the body. It is surrounded by a mass of nuclei in the second one-fifth. The intestine is enlarged at its origin, then diminished to a diameter of about 25μ, which is maintained until it joins the rectum, which is about 30μ in diameter. Nuclei like those seen in the wall of the remainder of the alimentary tract are absent from the rectum. The anus is closed and presents a rounded projection as in stage 1. Against the wall of the intestine about 600μ from the anterior end of the body there is an elongated

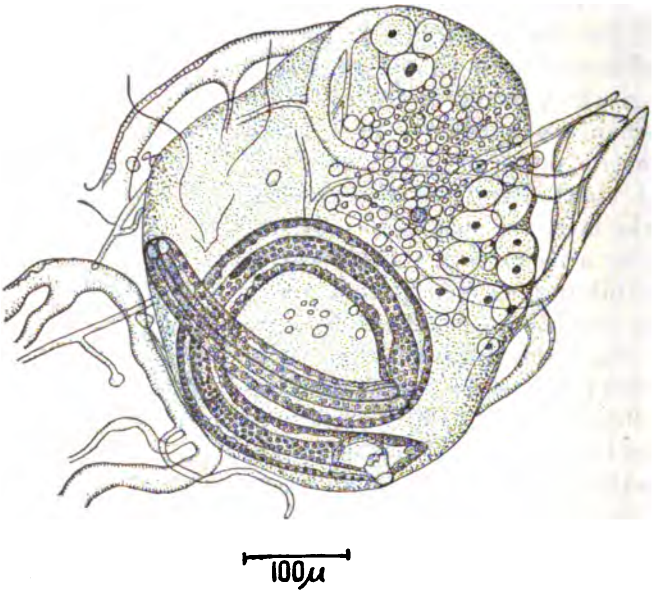

FIG. 12.—*Habronema muscæ*. Larva (Stage 2) inclosed in a cyst, from abdomen of fly pupa. × 140. Original.

nucleated mass, about 30μ long, evidently the genital primordium. The tail of the worm is bluntly pointed as in stage 1, and the anus is about 45μ from the tip.

Stage 3.—Following stage 2 the parasite evidently sheds its skin and abandons its cyst. It increases in length and in thickness. The prominent nuclei of the alimentary tract and body wall are no longer evident, the esophagus shows a differentiation into two parts, a shorter, narrower, more transparent anterior portion and a longer, thicker, granular posterior portion, and the pharynx becomes longer. Stage 3 is shown in figures 13, 14. The worm figured was taken from the abdomen of a newly emerged fly August 30 which had been bred in a culture of horse feces collected August 9. This worm measured about 2.2 mm. in length by about 70μ in width, which was nearly uniform throughout most of its length, becoming slightly less toward the anterior end. The slender pharynx measured about 38μ in length and was surrounded by clear spaces. The anterior clear portion of the esophagus measured about 100μ in length by 15μ in diameter, and at its junction with the second portion of the esophagus was surrounded by a nerve ring. The second portion of the esophagus at its beginning was enlarged rather suddenly to a diameter of 25μ and then more gradually to a maximum of about 32μ near its posterior end. In the neighborhood of the nerve ring the end of the first portion and the beginning of the second portion are surrounded by a mass (about 100μ long) of promi-

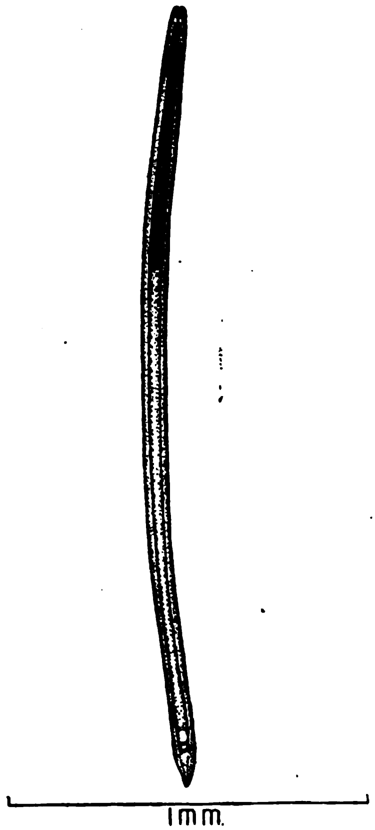

FIG. 13.—*Habronema muscæ.* Larva (Stage 3) from abdomen of newly emerged fly. × 47. Original.

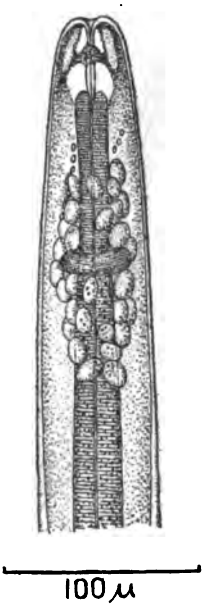

FIG. 14.—*Habronema muscæ.* Larva (Stage 3) from abdomen of newly emerged fly. Anterior end of worm shown in fig. 13. × 250. Original.

nent large nuclei. The posterior end of the esophagus was about 720μ from the anterior end of the body. The intestine, about 30μ in diameter, varied little in size until the rectum was reached. The rectum was short, slightly larger than the intestine and, as in preceding stages, was closed to the exterior by a rounded operculum-like structure which projected outward at the anus. The anus was about 100μ from the tail, which diminished gradually in thickness from the anal region and terminated in a rather blunt point. This worm was about

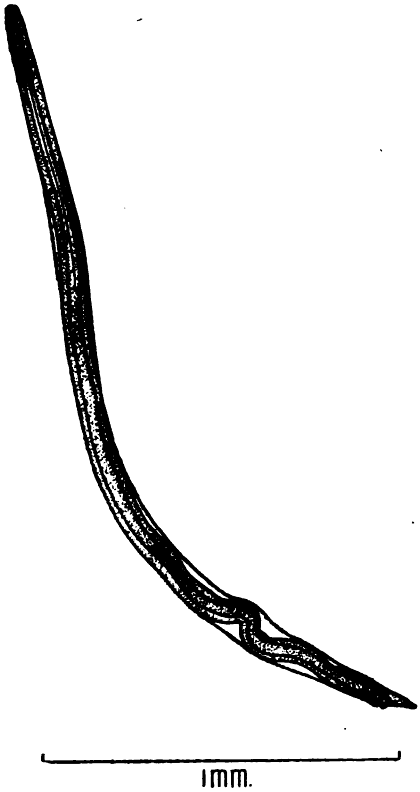

Fig. 15.—*Habronema muscæ*. Larva (Stage 4) from abdomen of newly emerged fly. × 47. Original.

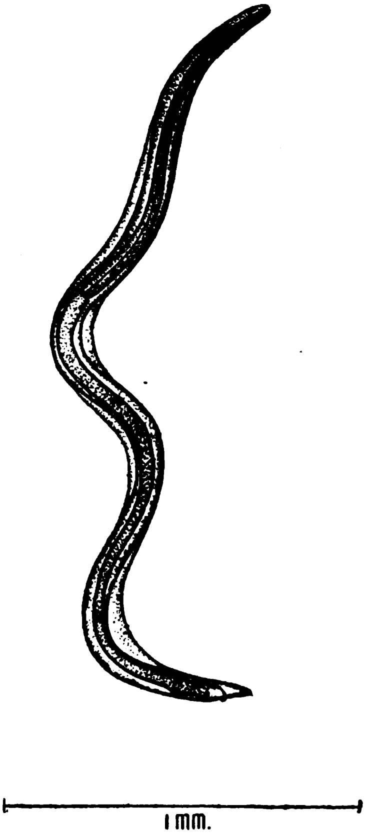

Fig. 16.—*Habronema muscæ*. Larva (Stage 5) from thorax of newly emerged fly. × 46. Original.

to molt, as an outer and an inner cuticle were plainly evident in certain regions of the body.

Stage 4.—Between stages 3 and 4 another molt evidently occurs. The vacuoles surrounding the pharynx disappear and the esophagus increases slightly in length. The entire worm becomes somewhat longer. The anal operculum remains. The worm shown in fig. 15 was taken August 25 from the abdomen of a newly emerged fly bred in horse feces collected August 9. The length, not allowing for the curved condition of the worm inside the outer cuticle, is about 2.2 mm. and the maximum width about 70µ. The pharynx, which is now no longer closed as in preceding stages, measures about 45µ in length. The posterior end of the esophagus is about 800µ from the anterior end of the body, both the anterior and posterior portions being slightly longer than in the preceding stage. The nerve ring is about 170µ from the anterior end of the body. Four small papillæ are evident on the head. The anus, still closed, is about 80µ from the tip of the tail, which is similar in shape to that of the preceding stage. The worm is about to molt.

Stage 5.—This stage follows stage 4 after an intervening molt. The pharynx is not so widely open, the esophagus is longer, the entire worm is somewhat longer and thicker, and the spiny tail, a constant feature of the next following stage, becomes evident beneath the outer cuticle. The length of the worm shown in figure 16, which was taken August 28 from the thorax of a newly emerged fly bred in horse feces collected August 9, is about 2.5 mm. The maximum breadth is about 75µ. The length of the pharynx, whose cylindrical cavity is somewhat narrower than in the preceding stage (fig. 15), is about 45µ. The posterior end of the esophagus is about 1 mm. from the anterior end of the body, both portions of the esophagus, but particularly the posterior portion, being somewhat longer than in the preceding stage. The same is still closed, and is about 80µ from the tip of the tail. Just prior to the molt which leads to stage 6, the spines, characteristic of the final larval stages, appear on the tip of the tail beneath the outer cuticle. The rectum is distended as in all the preceding stages.

Stage 6.—In flies: In this stage, which is the final larval stage, and the stage which the worms are usually in when found in the head or proboscis of infested flies, the length varies from 2.6 to 3.2 mm. and the width at the widest part from 55 to 70µ. The width is nearly uniform in the region between the beginning of the second part of the pharynx and the middle of the body, tapering posteriorly and at the anterior end. The head is rounded, and the tail pointed with a small rounded tip ornamented with tiny spines (fig. 19). Small papillæ, at least four and apparently six in number, may sometimes be made out on the head. The pharynx is cylindrical, about four times as long as broad. The anterior portion of the esophagus is less than half the average width of the posterior portion and about one-fourth the length of the latter. The anus in this stage is no longer closed. The worm shown in figures 17 and 18, taken August 28 from the head of a newly emerged fly bred in horse feces collected August 9, measures about 3 mm. in length. The pharynx is 45µ long by 12µ in width. Width of body at base of pharynx, 50µ; nerve ring 150μ from the anterior end of body; diameter of body at nerve ring, 65μ. The anterior portion of the esophagus is slender, averaging about 11μ in width; its length is 200μ. The posterior end of the esophagus is 1 mm. from the anterior end of the body. The width of its posterior portion varies from about 25μ a short distance behind its junction with the anterior portion to about 50μ at its posterior end. The width of the body at the base of the esophagus is 70μ and is practically the same at the middle of the body. The intestine, nearly uniform in diameter, has a maximum width of about 40μ. The anus is 100μ from the tip of the tail, and the diameter of the body (dorsoventral) at the anus is about 33μ. The tail is slightly

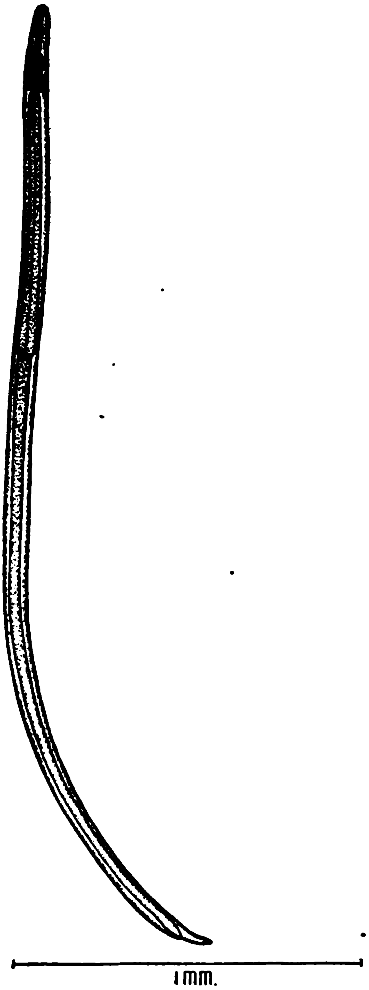

FIG. 17.—*Habronema muscæ*. Larva (Stage 6) from head of newly emerged fly. × 46. Original.

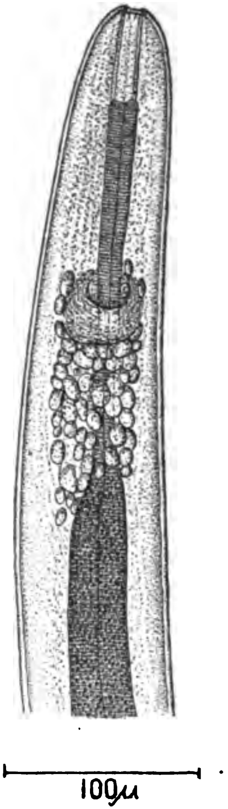

FIG. 18.—*Habronema muscæ*. Larva (Stage 6) from head of newly emerged fly. Anterior end of worm shown in fig. 17. × 250. Original.

bent dorsalwards. Under high magnification a few small short longitudinal ridges may be seen on the inner surface of the pharynx at its anterior end. These are faintly evident in figure 18. The mass of nuclei posterior of the nerve ring shown in this figure are a conspicuous feature of the worm at this stage. It is these nuclei which were misinterpreted by Carter as reproductive organs.

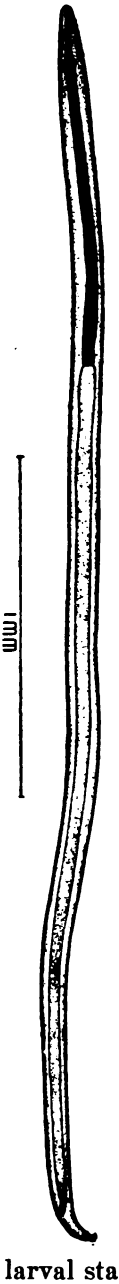

FIG. 20.—*Habronema muscæ.* Larva (Stage 6) from stomach of horse. × 45. Original.

In horses: The final larval stage in the fly is the first stage of development in which the worm is found in the horse. Worms in this stage were found among numerous individuals collected from the stomach of a horse, September 7, 1911, at Omaha, Nebr. Examination of the worms from this horse showed two or three specimens of a *Trichostrongylus*, but most of them were filarioid worms in various stages of growth, the adults all belonging to a single species very similar to *Spiroptera microstoma.* The relative size of several worms from this horse are shown in figure 23, *c–i.*

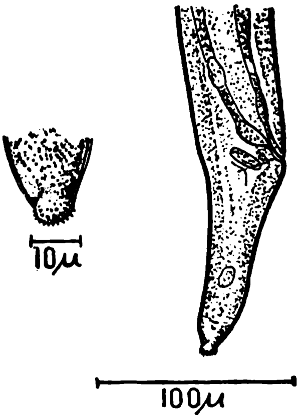

FIG. 19.—*Habronema muscæ.* **Larva (Stage 6) from newly emerged fly. Posterior end. × 260. Drawing at left shows spinose tip of tail more highly magnified. × 650. Original.**

The fact that the adults were all of one species, and that the younger stages formed a series between the adult on one hand and the larval *Habronema muscæ* on the other showed quite clearly that *Habronema muscæ* of the fly is the larval stage of a parasite whose adult occurs in the stomach of the horse. This parasite, as shown later, though similar to *Spiroptera microstoma*, is distinctly different from this form. Under the rules of nomenclature it takes the name *Habronema muscæ*, and *Spiroptera microstoma*, with which it is congeneric, becomes *Habronema microstoma*, as noted on my preliminary report (Ransom, 1911).

It is fair to presume that *Habronema microstoma* has a life history similar to that of *H. muscæ*, and as already noted it may be that the form from *Stomoxys calcitrans* called *Filaria stomoxeos* by Linstow is the larval stage of *H. microstoma.*

The infection of horses with *H. muscæ* is apparently brought about by the swallowing of infested flies. That horses actually swallow flies is a fact evident to anyone who has observed horses during the fly season. The swallowing of dead flies as a possible method of infection has already been mentioned, and the possibility that the worms may escape from the proboscis while the fly is feeding on the moist mucous membrane of a horse's mouth has also been noted.

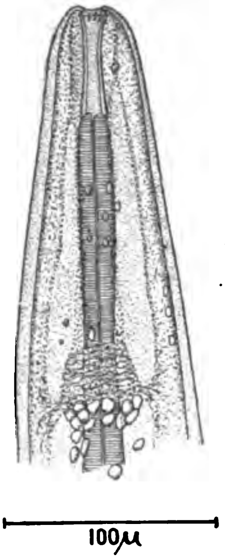

FIG. 21. – *Habronema muscæ*. Larva (Stage 6) from stomach of horse. Anterior end. × 275. Original.

The larva shown in figures 20 to 22 exhibits no further development beyond the final stage of development found in the fly except a slight increase in length and thickness, and it is considered unlikely that an intervening molt has occurred. The length is 3.7 mm. The pharynx is 45μ long. Width of body at the base of the pharynx, 50μ. Nerve ring 160μ from the anterior end of the body. Width of body at nerve ring 80μ. Length of first part of esophagus 175μ. Base of esophagus 1.05 mm. from anterior end of body. Width of body at base of esophagus and at middle of body 90μ; anus 125μ from the tip of the tail. Diameter (dorsal-ventral) of body at anus, 50μ. The little ridges at the anterior end of the pharynx, sometimes apparent in larvæ from flies, were plainly evident in this specimen. The tail is bent dorsalwards as in the final larval stage found in flies. This worm is evidently nearly ready to molt. The worm shown in figure 23, *c*, which is in the same stage of development, though somewhat smaller, measuring only 3.5 mm. in length, is also ready to molt.

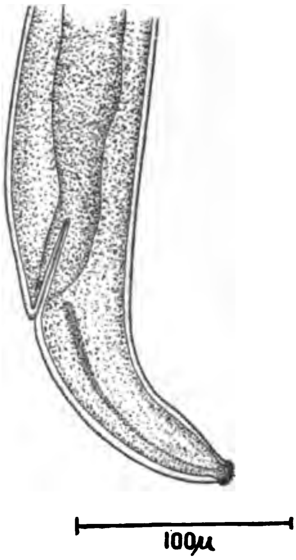

FIG. 22.—*Habronema muscæ*. Larva (Stage 6) from stomach of horse. Posterior end. × 275. Original.

LATER IMMATURE STAGES IN HORSES.

The first molt of the worm during its development in the horse is accompanied by no appreciable change in structure. Even the spiny condition of the tip of the tail is retained. Such a worm is shown in figure 23, *d*. The esophagus is relatively a little shorter, and, as shown in figure 23, *e–i*, becomes relatively still shorter in later stages of development. In stages later than that shown in figure 23, *d*, the spiny knobbed tail is no longer present.

Apparently, at least four molts, and possibly five, occur in the development of the worm in the horse, between the earliest stage

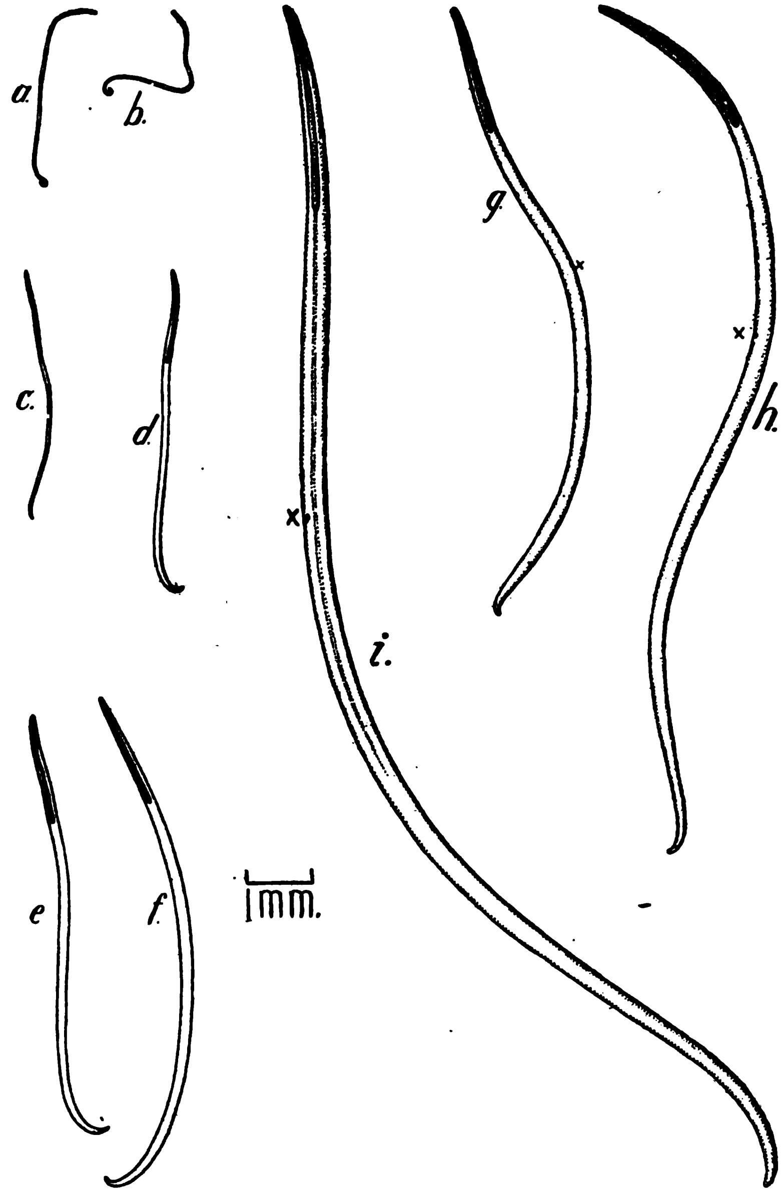

FIG. 23.—*Habronema muscæ.* Larvæ, immature stages, and adults. *a, b,* larvæ (Stage 6) from fly; *c,* larva (Stage 6) from stomach of horse; *d,* larva (later stage) from stomach of horse; *e, f, g,* later immature stages from stomach of horse; *h, i,* adult females from of horse. X indicates position of vulva. × 9. Original.

and the adult. All five of the worms shown in figure 23, *c–g*, are in process of molting. The two shown in figure 23, *c*, *d*, have spiny tails, a character which has disappeared in those shown in figure 23, *c–g*.

The one shown in figure 23, *f*, has the position of the vulva evident beneath the old cuticle. A stage closely following the one shown in figure 23, *f*, is shown in figure 23, *g*. In this worm the vulva opened to the exterior.

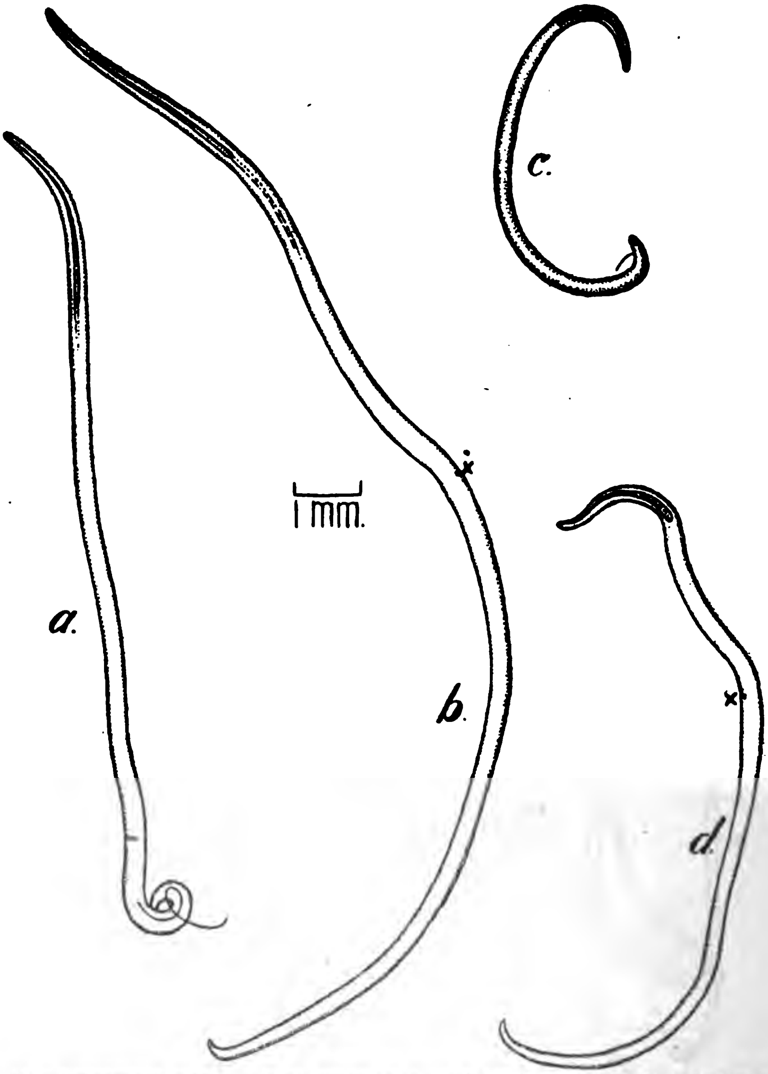

FIG. 24.—*Habronema muscæ*. Adult males (*a*, *c*) and females (*b*, *d*). X indicates position of vulva. × 9. Original.

ADULT.

The adult male *Habronema muscæ* (fig. 24, *a*, *c*) varies in length from 8 to 14 mm., and from 250 to 300μ in maximum width, which is attained near the posterior end. The length of the adult female (fig. 24, *b*, *d*; fig. 23, *h*, *i*) varies from 13 to 22 mm., and the width in the region of the vulva from 250 to 400μ. *Habronema microstoma*, in the case of the male (fig. 25, *a*, *c*), varies in length from 9 to 16

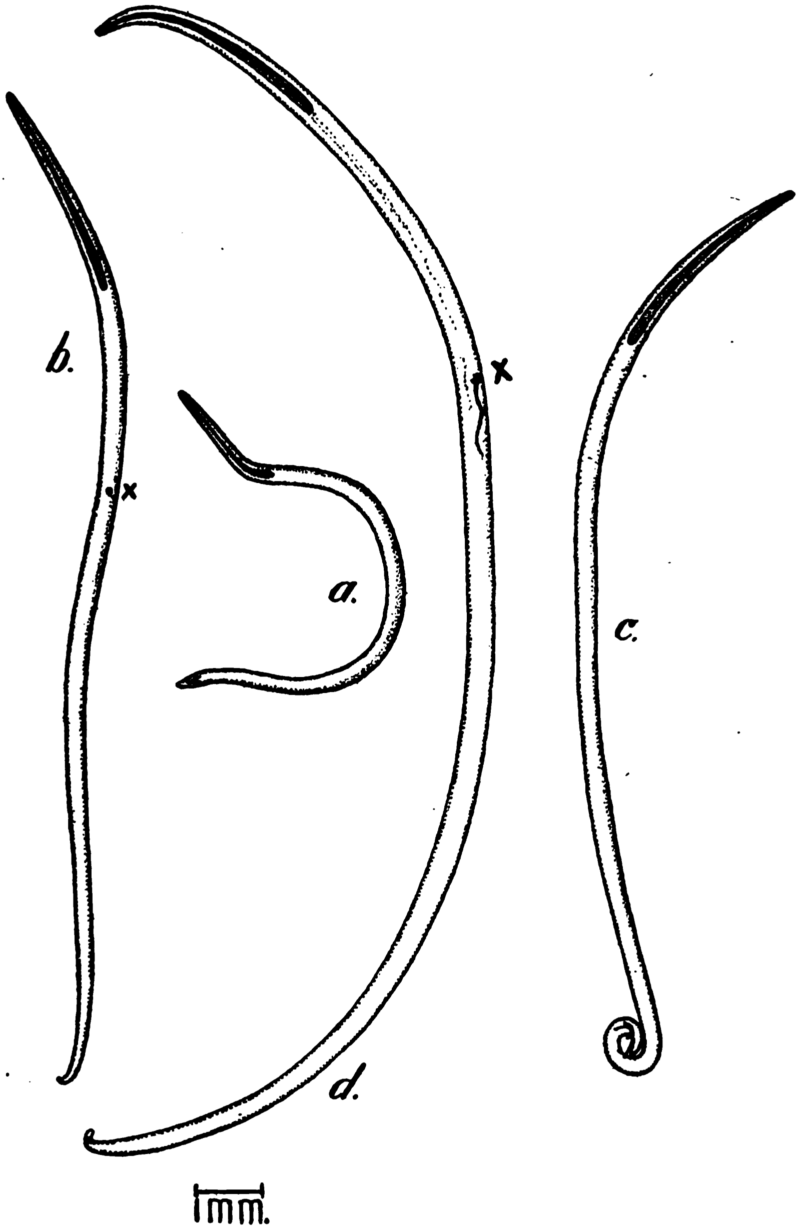

FIG. 25.—*Habronema microstoma.* Adult males (*a*, *c*) and females (*b*, *d*). X indicates position of vulva. × 9. Original.

mm. (11 to 22 mm., Schneider) and from 250 to 300μ in maximum width, which is attained at a point some distance posterior of the base of the esophagus. The female *H. microstoma* (fig. 25, *b*, *d*) varies in length from 15 to 25 mm. and in width (at the vulva) from 330 to 500μ. *Habronema muscæ* thus averages somewhat smaller in size than *H. microstoma.* In both species there is a marked transverse striation or corrugation of the cuticle. The general plan of the head, mouth parts, pharynx, and esophagus is the same in both *H. muscæ* (figs. 26, 27) and *H. microstoma* (figs. 28, 29), but in the details of these structures there are certain distinct differences. The head of the latter has a broader, squarer, more truncate appearance. In both the mouth is bordered by 2 lateral trilobed lips, or if differently interpreted by 2 lateral and 4 submedian lips. The head is armed with 2 lateral and 4 submedian papillæ, the latter being situated somewhat posterior of the former. From a lateral view the middle lobe of each lateral lip presents a nearly quadrangular outline, with the lateral papilla near its anterior border.

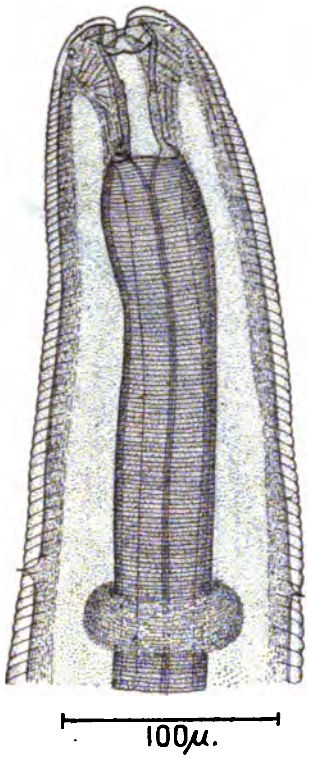

Fig. 26.—*Habronema muscæ*. Anterior end of adult. Drawn from specimen shown in fig. 23, *h*. × 280. Original.

The pharynx whose structure is somewhat complicated is smaller and relatively more slender in *H. muscæ* than in *H. microstoma.* In both species it is compressed laterally. In *H. microstoma* a tridentate process, not present in *H. muscæ*, projects into the mouth cavity from the dorsal wall of the anterior part of the pharynx, and a similar process is present on the ventral wall.

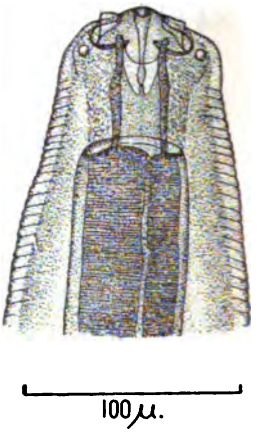

Fig. 27.—*Habronema muscæ*. Anterior end of adult. Lateral view. Drawn from specimen shown in fig. 24, *b*. × 280. Original.

In the adult as in the larval *H. muscæ* the esophagus is distinctly divided into two parts, a narrow, short anterior portion and a broader, longer posterior portion. The slender anterior portion is surrounded by a nerve ring about 300μ (in the female) from the anterior end of the body, and in the region of the nerve ring there is a pair of short, slender, bristlelike cervical papillæ (fig. 26). The nerve ring and cervical papillæ in *H. microstoma* are located 300 to 350μ (in the female) from the anterior end of the body (fig. 28). The distance from the anterior end of the body to the base of the esophagus varied in several specimens (females) of *H. muscæ* from 2.3 to 3.5 mm. In females of *H. microstoma* this distance varied from 3 to 3.8 mm.

In both *H. muscæ* and *H. microstoma* a narrow lateral membrane begins posterior of the left cervical papilla and extends backward along the left side of the body. In the male it extends to or even beyond the middle of the body and in the female it ends within a short distance in front of or behind the vulva. A lateral membrane on the right side of the body is lacking. The unusual circumstance in which a lateral membrane occurs on one side of the body and a corresponding membrane is absent from the other side has been noted in the case of *Arduenna strongylina* by Schneider (1866 *a*) and others.

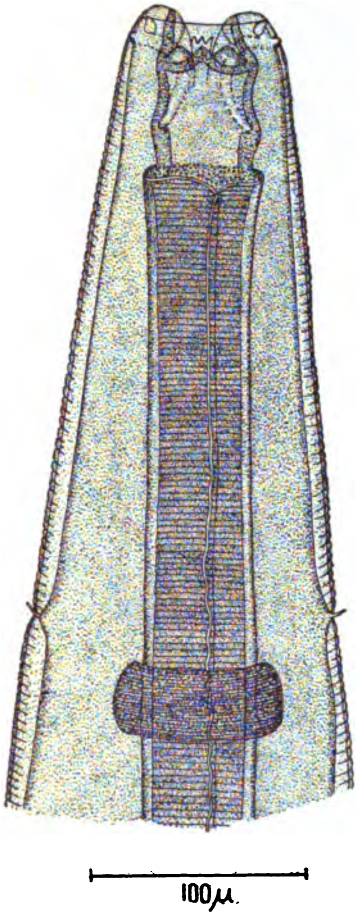

Fig. 28.—***Habronema microstoma*.** Anterior end of adult. Drawn from specimen shown in fig. 25, *b*. × 280. Original.

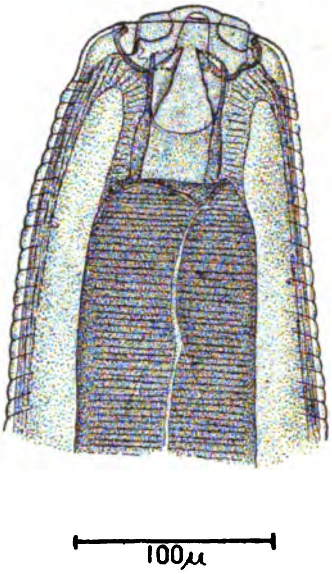

Fig. 29.—***Habronema microstoma*.** Anterior end of adult. Lateral view. Drawn from specimen shown in fig. 25, *d*. × 260. Original.

The tail of the male curves ventrally in both *H. muscæ* and *H. microstoma*, usually describing a single turn of a spiral (figs. 30, 31). Narrow, almost symmetrical, bursal wings are present, measuring about 500μ in length and extending to the tip of the tail in both species. Stalked genital papillæ, pre-anal and post-anal, are present.

In *H. muscæ* there are four pairs of pre-anal papillæ, two pairs of which are ad-anal rather than pre-anal. On the right side of the bursa there is one post-anal papilla, about half way between the anus and the tip of the tail, and on the left side a papilla in a corresponding location. A short distance in front of the latter and nearer the median line is another papilla. A corresponding papilla on the right side of the bursa is lacking. The arrangement of the papillæ will be better understood from the figures than from a description (figs. 30, 32).

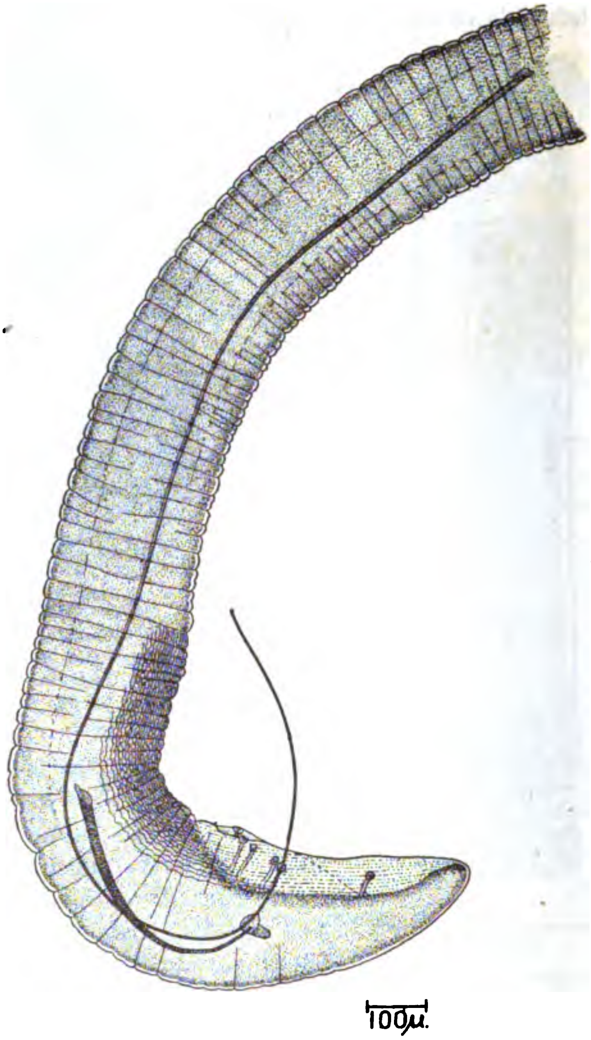

FIG. 30.—*Habronema muscæ.* Tail of male. Lateral view. Drawn from specimen shown in fig. 24, *c.* × 80. Original.

In *H. microstoma* there are four pairs of pre-anal papillæ, those of the left side being somewhat further anterior than those of the right side. Instead of three post-anal papillæ, as in *H. muscæ*, there are

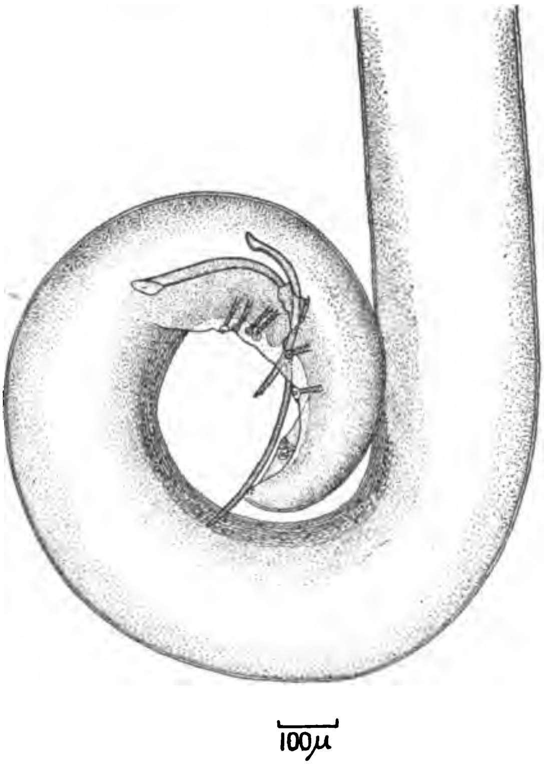

Fig. 31.—*Hebronema microstoma.* Tail of male. Lateral view. Drawn from specimen shown in fig. 25, *c.* × 80. Original.

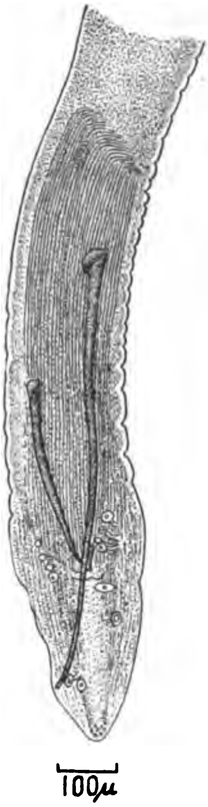

Fig. 33.—*Habronema microstoma.* Tail of male. Ventral view. Drawn from specimen shown in fig. 25, *a.* × 80. Original.

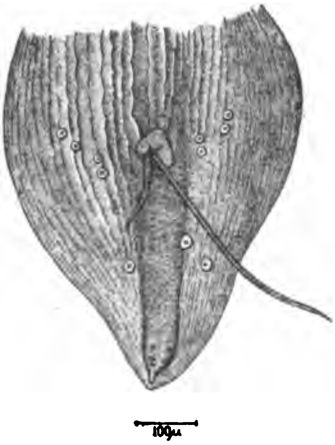

Fig. 32.—*Habronema muscæ.* Tail of male. Ventral view. × 80. Original

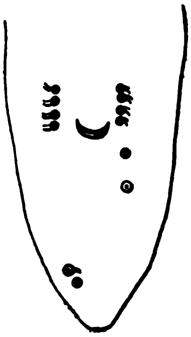

Fig. 34.—*Habronema microstoma.* Tail of male. Ventral view × 62. After Schneider, 1866 *a*, p. 98.

four. On the left side there is one near the anus, and another a short distance posterior of this one. The two post-anal papillæ on the right side are close together and not far removed from the tip of the tail. The arrangement of the genital papillæ is shown in the figures (figs. 31, 33, 34).

In both *H. muscæ* and *H. microstoma* the ventral surface of the tip of the tail of the male is supplied with a cluster of very small papillæ, six of which are somewhat more prominent than the others. In all, there are 10 or 12 of these papillæ. They are considerably larger and more conspicuous in *H. muscæ* than in *H. microstoma.*

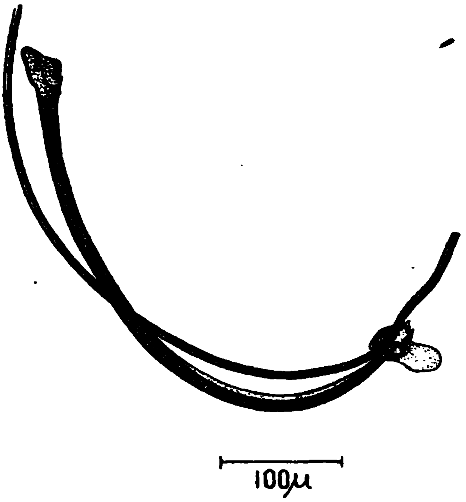

FIG. 35.—*Habronema muscæ*. Spicules and gubernaculum of male. Only a portion of the left spicule is shown. Drawn from specimen shown in figs. 24, c, and 30. × 160. Original.

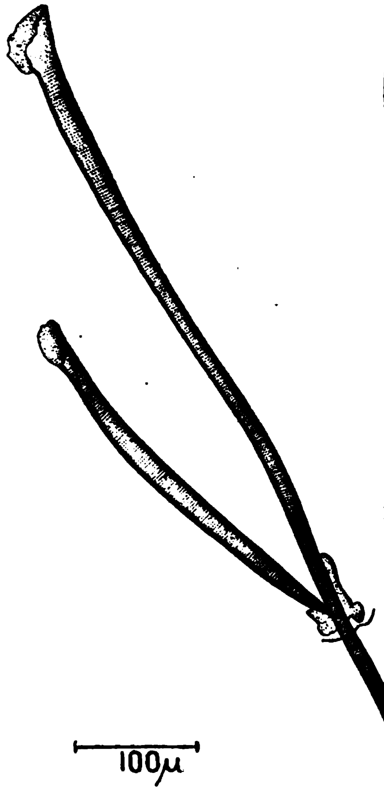

FIG. 36.—*Habronema microstoma*. Spicules and gubernaculum of male. Drawn from specimen shown in figs. 25, *a*, and 33. × 160. Original.

The cuticle on the ventral surface of the posterior portion of the body of the male, beginning about a millimeter to a millimeter and a half from the tip of the tail, is marked by numerous longitudinal scalloped ridges; in fact, the entire ventral face of the bursa is marked with delicate longitudinal ridges and small vesicular excrescences having a linear arrangement.

The spicules in *H. muscæ* (figs. 30, 35) are quite dissimilar. The left spicule is long, slender, about 2.5 mm. in length, about 10μ, in diameter near its proximal end, tapering to a sharp point, and measures about 5μ in diameter at its middle. The right spicule is shorter and thicker, about 500μ long, tapering from a thickness of about 20μ near its proximal end to a point posteriorly, and measuring about 10μ at its middle. Near the anal opening the spicules are surrounded by a small, irregularly shaped gubernaculum.

The left spicule of *H. microstoma* (figs. 31, 33, 36) is much shorter and thicker than that of *H. muscæ*. It measures about 800μ in length, tapering from a diameter of about 20μ near its anterior end to a diameter of 8μ at its posterior end, and measuring about 15μ in diameter at its middle. The right spicule has a length of about 350μ, and a diameter of about 15μ near its anterior end. It increases in thickness posteriorly, reach-

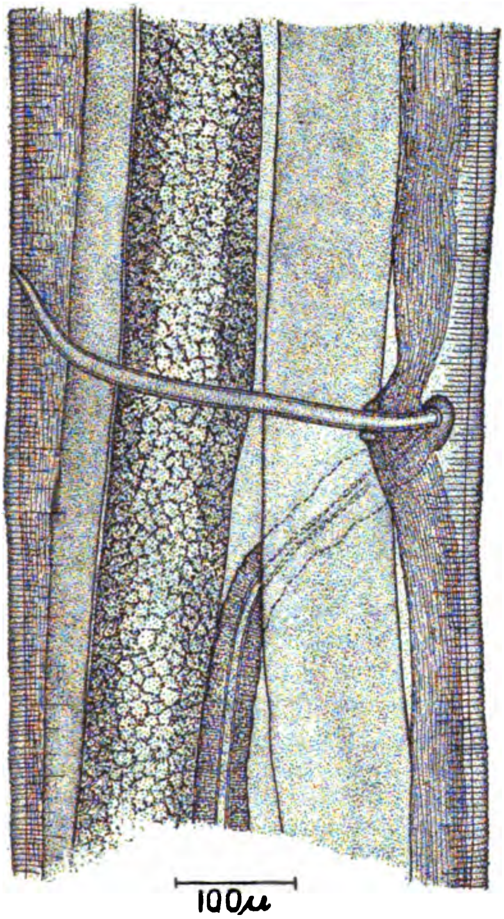

FIG. 37.—*Habronema muscæ*. Region of vulva of female. Drawn from specimen shown in fig. 23, *i*. × 160. Original.

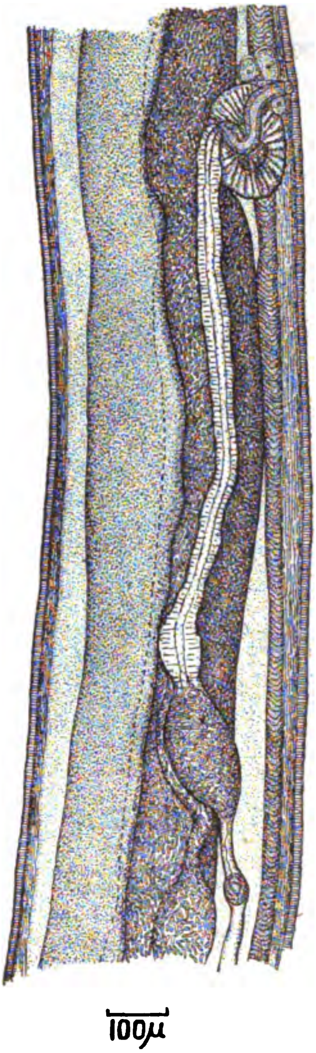

FIG. 38.—*Habronema microstoma*. Region of vulva of female. Drawn from specimen shown in fig. 25, *d*. × 80. Original.

ing a diameter of about 20μ at its middle, then decreases again, and terminates in a point with a small barb about 6μ from the tip. Near the anus the spicules, as in *H. muscæ*, are surrounded by a small, irregularly shaped gubernaculum.

In *H. muscæ* the vulva is located about a third of the length of the body from the anterior end (figs. 23, 24, *x*); in *H. microstoma* the distance of the vulva from the anterior end is slightly over a third the body length (fig. 25, *x*). The vulva of *H. muscæ* is very small (fig. 37), and is displaced dorsalward out of the usual mid-ventral position. It may be dorsal in position, or may even be displaced still further and be located on the left side of the body a slight distance dorsal of the lateral membrane. A somewhat similar displacement of the vulva has been noted by Ciurea in *Arduenna strongylina*. The distal portion of the vagina measures not over 15μ in diameter and is without a muscular sheath. From the vulva it passes transversely halfway or more (according to the degree of displacement of the vulva) around the body beneath the cuticle in the superficial portion of the body wall, then enters the body cavity, becoming clothed with a muscular layer, and passes posteriorly, joining the two uteri about 1.5 mm. posterior of the vulva. Including the muscular sheath, the diameter of the vagina after it enters the body cavity is about 4.5μ.

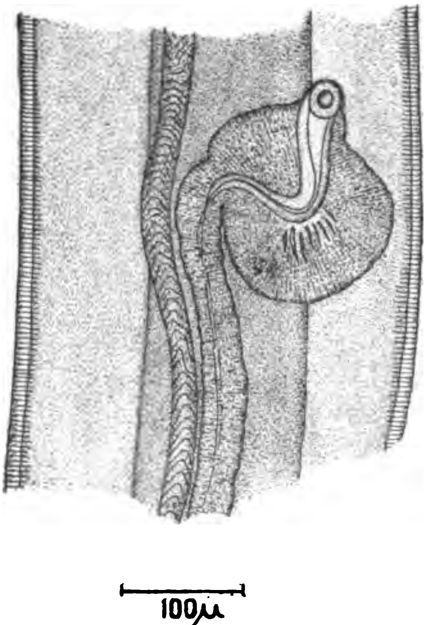

FIG. 39.—*Habronema microstoma*. Region of vulva of female. Drawn from specimen shown in figs. 25, *b*, and 29. × 160. Original.

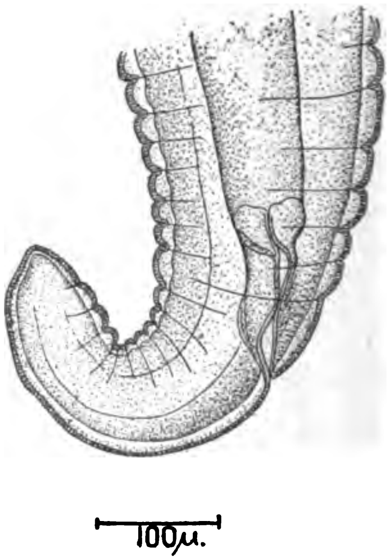

FIG. 40.—*Habronema muscæ*. Tail of female. Lateral view. × 160. Original.

In *H. microstoma* the vulva is rather large, its diameter, including its chitinous margin, being about 30μ (figs. 38, 39). It is not displaced more than very slightly from the mid-ventral position, if at all. The vagina passes inward and backward, then curves forward for a very short distance, and backward again, entering the body cavity, and continuing then in a straight course posteriorly to join the terminal portion of the two uteri. The vagina, in the region of the short **S**-shaped curve, is surrounded by a globular mass of muscular tissue. This muscular mass, 150 to 200μ in diameter, is a conspicuous structure in transparent specimens, located immediately posterior of the vulva. The vagina, throughout its course posteriorly from the globular muscle mass which surrounds its distal portion to the uteri, is surrounded by a muscular layer. Including this layer, its diameter is from 40 to 50μ. The length of the vagina, measured in a straight line from the vulva to the point where it joins the uteri, is about 1 mm.

H. muscæ is thus quite different from *H. microstoma* with regard to the vulva and vagina. The vulva is much smaller, the vagina passes halfway around the body before entering the body cavity, and is without the distal **S**-shaped curve surrounded by a muscle bulb. These characteristic features of *H. muscæ* are already evident in young worms 7 mm. long, which have not yet undergone the fourth molt in their development in the horse.

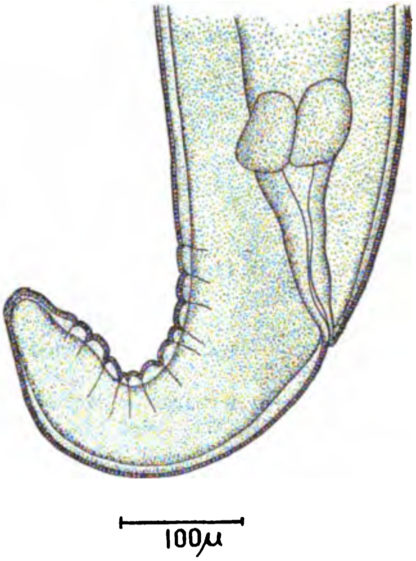

FIG. 41.—*Habronema microstoma.* Tail of female. Lateral view. Drawn from specimen shown in figs. 25, *b*, 29, and 39. × 160. Original.

The tail of the female is very similar in *H. muscæ* (fig. 40) and *H. microstoma* (fig. 41), rather plump, with rounded tip, and more or less curved dorsalward, the post-anal portion measuring 300 to 350μ in length in *H. muscæ* and slightly more in *H. microstoma.*

ADDENDUM.

Since July 15, 1912, when the manuscript of this bulletin was completed and submitted for publication, two articles containing references to *Habronema* have come to hand.

Seurat (1912, 778) reports the occurrence of both *H. muscæ* and *H. microstoma* in horses and mules in Algiers, and describes and figures the ovijector in both species.

Johnston (1912, 76) reports the presence of *Habronema muscæ* in *Musca domestica* at Brisbane and in *M. domestica* and *Stomoxys calcitrans* at Sydney, Australia.

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Issued February 27, 1913.

U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ANIMAL INDUSTRY.—BULLETIN 164.

A. D. MELVIN, CHIEF OF BUREAU.

DAIRY HERD RECORDS.

(FROM 1899 TO 1908, INCLUSIVE.)

A DIGEST PREPARED BY THE DAIRY DIVISION
FROM DATA COLLECTED BY W. D. HOARD.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1913.

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A FOREWORD.

Mr. B. H. Rawl, chief of the Dairy Division, under whose immediate supervision the important facts of this combined "cow census" are collected and presented in the form of a Government bulletin, has asked me to say a few words concerning this enterprise.

This census work was inaugurated for the reason that there was nowhere to be found a basis of fair and comprehensive calculation as to the economic relation of the dairy farmers of the United States to their business. The farmers kept no records. There were no bureaus of statistics that thought it worth while to look into these conditions. Neither the Federal Government nor the States established agencies of inquiry and analysis. Everywhere, from the farmer to the State and General Government, it was guesswork and only guesswork as to the actual relation of the cow to the farmer.

Serious discontent was felt in the dairy ranks everywhere. Something was wrong. I very strongly suspected that a broad, comprehensive, and thorough investigation would show that the lack of profit in ordinary dairy farming was due to the fact that farmers as a rule did not comprehend what dairy farming really meant—that they did not comprehend rightly the forces that must be put in motion to bring financial success.

This "cow census" work was started as a private enterprise, to get at the real facts. Experts, who thoroughly understood dairying, dairy cattle, and right dairy conditions, were employed to do the work. They would visit the farmer and get hold of all the facts at the farm end first. Then they would visit the creamery, where an accurate record was kept of the milk yield of the herd and of the returns in cash. One squared by the other told the story. Many conclusions have been worked out of this great mass of data.

The one great and paramount conclusion, overtopping all others, is that loss of profit in dairying is occasioned in nine cases out of ten by a lack of sound dairy intelligence on the part of the farmer who is behind the cow.

W. D. Hoard.

Fort Atkinson, Wis.

DAIRY HERD RECOI

REVIEW OF EARLY CONDITI

The introduction of the factory system of
products, the invention of the cream separato
of the Babcock test mark a revolution in the
in the United States. In pioneer days the f
widely scattered settlers pastured on uninclosec
the woods near the clearings; and when in win
sary to stable them little except straw and hay,
of inferior quality, was fed. In those days the p
say nothing of butter and cheese, during winter
the average farm. Naturally enough, when the
rough or uninclosed lands and in winter found
from the straw stack, the cost of producing milk
by the labor of milking, which usually fell to th
and the expense of building the rude barn whic
in winter.

In the year 1851 the first of the three great le
the dairy industry to a higher plane was put in
factory system of making cheese was adopted.
the principle of cooperative effort so successful i
try was applied to the manufacture of butter. T
were mere shells of buildings, totally unfit for use
there been milk available for cheese or butter ma

With the close of the neighborhood cheese fact
the fall another care was laid upon the busy
event marked the beginning of the season to m
winter's supply of butter, which had to be don
went on their annual all-winter vacation. Half
majority of farmers had no faith in the specia
either milk or beef. But the increasing demand
to the growth of our urban population was a po
its all-the-year-round production, so that here an
found a farmer who had broken away from his ea
actually had cows in milk all winter.

By the year 1887, which marks the date of the f
there were in the United States in round numbers
tories and creameries in operation, whose patro

their milk and cream at stated periods, usually monthly. As they compared their receipts month by month and season by season, it became known that some of them were getting uniformly higher returns per cow than their neighbors. Wherever a patron set out honestly to discover why his neighbor's cows gave more satisfactory returns than his own, he found that it was owing to one or more of the following causes: Superior cows, better management, more liberal feeding, or better care on the part of the owner.

The questions whether it really paid to make any provision to tide the cows over any temporary scarcity of pasture in summer or to care for them in winter so as to have milk were about this time live issues at all farmers' meetings where dairying was discussed. On the one side were ranged the great mass of the farmers who claimed that milk produced in winter cost more than it was worth, that a cow would give as much milk in six months as she would if milked the year round, that forced and prolonged production would soon put an end to her usefulness, and that stable milk contained a nasty, cowy flavor from which a first-class article of butter or cheese could not be made; in which last view they were upheld by the majority of the butter and cheese makers.

On the other side were farmers, few in number but undeniably prospering, who had broken away from the old order of things, and who claimed that their cows yielded them not only higher gross returns but larger profits; who maintained that it paid them to stable their cows comfortably in winter, and that their herds gave them satisfactory returns for a more expensive winter ration containing grain. Here and there among them was to be found a farmer who had experimented with and was prepared to recommend a new feed called ensilage, by the use of which, he was convinced, he had reduced materially the cost of producing winter milk.

THE ORIGINAL COW CENSUS.

It was at this stage of the development of the dairy industry that in the year 1887, as has been stated, the first systematic effort in the United States to find out the actual cost of producing milk on a number of neighboring farms was undertaken by William D. Hoard. This work was carried out for Mr. Hoard in a very able way by Charles W. Jennings. The town of Ellisburg, N. Y., was chosen as a favorable place to carry out this investigation, which has since become known as "the original cow census." In this census there were included 5,507 cows, distributed on 367 farms, the milk being mostly sent to cheese factories. The purpose of the investigation was to discover the gross returns and approximate profits of the dairy on every farm visited and to ascertain the conditions under which the cows were kept in order to study the effects of breeding, care, feeding, and management. Incidentally some study was made of the influence of the personality of the attendants and of intelligent interest taken in dairying by the owner, as shown by his taste for agricultural and dairy literature.

When the results of this census were compiled it was calculated that the feed consumed by these 5,507 cows in one year, if sold at local market prices, would have brought nearly $25,000 more than the value of what the cows produced, including milk, cream, cheese, butter, skim milk, calves, and skins.

SCOPE AND METHOD OF THE LATER CANVASSES.

Following the original cow census at Ellisburg, N. Y., a series of similar investigations have been made in Iowa, Wisconsin, Indiana, Ohio, New York, Pennsylvania, Connecticut, Vermont, Minnesota, Michigan, New Hampshire, Massachusetts, and Illinois. Covering a period of 10 years from 1899 to 1908, inclusive, they represent the work of 26 district enumerations and include 2,163 herds, containing 28,447 cows. The consolidated records of these canvasses, numbered from 1 to 26, are shown later in the chronological order in which the canvasses were taken.

The method of conducting the canvasses necessarily varied to meet the conditions found. The general plan was to include in each canvass a sufficient number of representative herds to show fairly the equipment and practice prevailing in the territory covered. The canvasser would first visit the creamery, cheese factory, or receiving station. Here he usually had free access to the records and obtained figures showing the total receipts of milk or butterfat from each herd and the total amounts paid for such receipts during the year of the canvass. Having arranged his routes, the canvasser would then visit the farms selected and ascertain from the owner in each case the number of cows kept and particulars of the cost of feeding, together with such other information as was deemed necessary for the purpose of the investigation. These were taken down as stated by the farmer, usually from memory. The enumerators report that the farmers were perfectly willing to give them the information as soon as the object of the visit was explained. The enumerators frequently state, however, that the information collected in this way was not absolutely accurate.

LIMITATIONS OF THE WORK.

Certain limitations are inevitable in an investigation carried on by so many different canvassers in so many different localities and during so long a series of years. Exact definitions were not observed as to good and poor stables, although the general features of comfort, light, ventilation, and cleanliness are reported. Neither was any exact definition observed as to good or poor dairy type. Good dairy type was judged by the canvassers sometimes with large reliance upon breeding, but usually by observation of form. That the enumerators had difficulty in finding out from the owners, who rarely had any record except memory, the exact rations fed to their cows is evidenced by extracts from their reports, such as the following:

> Practically none of the farmers had any definite records of the cost of keeping a cow through the year, so that it was necessary here, as elsewhere, to compute the cost myself, after ascertaining what I could about the feeds used.
>
> As none whom I met knew exactly how much feed was used in a year, it will be understood that the cost of keeping, as estimated, is only approximate and relative.

At the close of one canvass an enumerator wrote:

> It is my belief that the cost of keep was fully $1 per cow too low in some dairies, as it was the practice of nearly every low-grade dairyman to figure his grain ration very low as soon as he saw that his receipts were low. And I am as fully convinced that the receipts were too high, as given in many of these poor dairies, the claim always being made that a large amount of butter, cream, and milk was consumed in their families.

It will be noticed that the South and extreme West, where dairying is not so important relatively, have not been included in these investigations, the work being confined to the northeastern quarter of the country. The later work was confined almost exclusively to creamery patrons and hence is frequently referred to as "creamery patron investigations."

For the purpose of these investigations the cow was usually credited only with the value of her whole milk and butter or butterfat, while the value of her skim milk, calf, manure, and final value as beef were not entered to her credit. It was assumed that these items balanced the charges for labor, housing, interest, insurance, and depreciation, also omitted, although these were items properly chargeable against the cow.

Other limitations can well be imagined when it is remembered that in order to determine any one point in dairy practice upon which doubt exists, care must be taken to have all details exactly alike except the one point under investigation. If, for instance, an experiment were undertaken to determine the value of silage as a feed for milch cows, and if the group of cows receiving silage were of dairy type, confined in comfortable stables, and bred to freshen in the fall, it would be difficult to compare the results with those obtained from a scrub herd fed on dry feed, in poor stables, and freshening in the spring, and say what proportion of the difference in yield was due to the superiority of silage as a feed.

VALUE OF THE RESULTS.

Values compensating for the limitations mentioned in the preceding chapter are found in the great number of herds and cows reported, the herds numbering 2,163 and the cows 28,447. The reports constitute a mass of most valuable material, such as never before has been available for study of the important questions involved.

Although the journal in which the original data were published has a wide circulation, and the publication of these investigations occasioned much comment when they appeared week after week, they are not now available except to the few who have preserved a file of the periodical covering the period of their issue. It is believed that the records of these investigations are of sufficient importance to entitle them to a permanent place in dairy literature, although the immense volume of the material prohibits publication of all the details. The aim of this digest is to present the most valuable features of this work so consolidated and compiled that they may be readily studied and compared.

For many years facts such as have been brought out in these canvasses have been demonstrated by experiments conducted by the various State experiment stations. Many of these experiments have been conducted with scientific exactness as to details over extended periods of time. Because of their confidence in the nature of this work, reading and thinking farmers have been convinced that they could apply the lessons taught and have had the courage to follow their convictions. While this is true of the more progressive type of dairy farmers, there was a large number who lacked this belief in the results obtained by the experiment stations; but when they found scores of prosperous dairymen all over the country making more money out of their cows, and ascribing their success to certain methods and equipment, and showing figures and other evidence to prove the truth of this claim, these unbelievers, who would have doubted the testimony of one or two eyewitnesses, could no longer doubt. They also obtained a basis for reckoning what they might expect to gain by adopting better methods themselves. Thus, the cow-census work has exercised a great and very helpful influence upon dairy practice.

DETAILS OF THE CANVASSES.

The results of each of the 26 canvasses are given in the following series of tables. The principal items recorded are:

(1) The number of herds and the number of cows in each of the classes designated.
(2) The yearly cost of feed per cow.
(3) Yearly production of milk and butter or butterfat.

(4) Returns for each dollar's worth of feed.
(5) Yearly net profit or loss per cow.
(6) Food cost of milk and of butter or butterfat.
(7) Herds showing profit or loss.

The above particulars are classified and compared so as to give information, in so far as the limitations of the methods of investigating these problems and the available data permit, on the following points:

(1) The cost of milk and butter from herds of dairy breeding as compared with herds classified as dual-purpose cattle or as scrubs.

(2) The cost of producing milk and butter where silage formed a part of the ration in comparison with the cost where the cows were on dry feed.

(3) The expense of producing milk and butter when cows were comfortably housed in severe weather, compared with the expense of production when cows were poorly stabled.

(4) The results obtained by readers and nonreaders of agricultural literature.

In addition to the above, some of the canvasses also give information on the following points:

(5) The benefit of using soiling crops to supplement pasture.

(6) An investigation into the cost of producing milk where alfalfa hay was used as compared with carbonaceous roughage.

(7) The cost of producing milk entirely from home-grown feeds as compared with the cost where some feed was bought to supplement the feeds grown on the farm.

(8) The effect on the milk flow of warming the drinking water.

(9) The advantages and disadvantages of raising heifers to replenish the herd.

(10) The revenue from milk delivered at a cooperative creamery compared with that from selling to a condensing factory.

Additional particulars are given in notes following each enumeration.

Following the records of the canvasses are a series of tables in which these averages of the different features reported upon are consolidated and arranged in such a manner that they may be conveniently compared.

CANVASS NO. 1.

Conducted in Jefferson County, Wis., 1899. C. P. Goodrich, canvasser. 100 herds, 1,804 cows.

[Average price of milk, 88.6 cents per 100 pounds; average price of butter, 18.8 cents per pound.]

Comparisons.	Number of herds.	Number of cows.	Yearly cost of feed per cow.	Pounds of milk yearly per cow.	Pounds of butter yearly per cow.	Returns for $1 worth of feed.	Net profit per cow yearly.	Food cost of milk per 100 pounds.	Food cost of butter per pound.	Profitable herds.	Unprofitable herds.
Total of canvass	100	1,804	$29.33	4,990	233	$1.50	$14.62	$0.588	$0.126	98	2
Cows:											
Dairy type	76	1,306	29.22	5,180	244	1.60	17.53	.564	.119	76	0
Dual purpose	24	498	29.67	4,390	196	1.22	6.67	.675	.151	22	2
Feed:											
Grain purchased	46	828	......	......	......	1.57	......	......	......	46	0
Feed home grown	54	976	......	......	......	1.45	......	......	......	52	2
Silage used	18	508	31.06	5,623	254	1.55	17.11	.552	.122	18	0
Stables:											
Good	55	990	29.37	5,192	247	1.61	19.92	.565	.115	55	0
Fair	33	504	......	......	......	1.47	......	......	......	33	0
Poor	12	220	28.83	3,950	177	1.14	4.04	.73	.163	10	2
Results:											
10 best herds	10	149	28.60	5,778	292	1.92	26.31	.494	.098	10	0
10 poorest herds	10	254	29.50	3,930	175	1.09	2.60	.75	.168	8	2

NOTES ON CANVASS NO. 1.

The only two herds in the canvass not making a profit have poor stables and scrub cows and buy no grain.

A comparison of the silage-fed herds with the average for the canvass is in favor of the silage-fed herds by an average net profit per cow of $2.49, an increase in the flow of milk of 633 pounds per cow, an increase in the quantity of butter of 21 pounds per cow, a decrease in the food cost of milk of 3.6 cents per 100 pounds, and an increased return of 5 cents for each dollar's worth of feed.

This increased profit from feeding silage would amount, in the average herd, to $70 per year. Of the herds fed silage, all but two are of dairy type, 12 have good stables, 6 have fair stables, none have poor stables.

A comparison as to the rations fed shows that those owners who buy their grain make 12 cents more on each dollar's worth of feed eaten than do the others who feed home-grown corn and oats. This illustrates the fact that, although it pays, generally speaking, to grow feed at home, it sometimes is cheaper to buy, especially if the home-grown feeds do not make up a properly balanced ration. For instance, it may be more economical to sell oats at a high price for horse feed and use the money to buy cottonseed meal, which will furnish protein for cows at a lower cost. Or if the home-grown feed consists wholly of carbohydrates, as corn and hay, it will pay well to buy nitrogenous feed rather than be without it.

The best 10 herds are all of dairy type, all but 1 have good stables, 3 are fed silage, and 7 are fed purchased protein.

Of the 10 poorest herds, only 1 is of dairy type, only 1 has a good stable, only 1 is fed silage, and 4 are fed purchased protein. This group produces only one-tenth as much net profit as the 10 best herds.

CANVASS NO. 2.

Conducted in Iowa, five counties, 1899. **Frank Kinsley**, canvasser. 100 herds, 882 cows.

[Average price of milk, 80.7 cents per 100 pounds; average price of butter, 19.4 cents per pound.]

Comparisons.	Number of herds.	Number of cows.	Yearly cost of feed per cow.	Pounds of milk yearly per cow.	Pounds of butter yearly per cow.	Returns for $1 worth of feed.	Net profit per cow yearly.	Food cost of milk per 100 pounds.	Food cost of butter per pound.	Profitable herds.	Unprofitable herds.
Total of canvass	100	882	$26.05	3,600	159	$1.16	$4.16	$0.702	$0.169	62	38
Cows:											
Dairy type	17	160	26.18	5,030	248	1.78	20.43	.52	.106	17	0
Dual purpose	83	722	25.46	3,150	134	1.02	.54	.82	.19	45	38
Feed: Use of silage	3	70	29.00	5,767	302	1.98	28.32	.503	.096	3	0
Reading:											
Owners read dairy literature	25	221	26.34	4,097	182	1.28	7.38	.642	.145	20	5
Owners do not read	75	661	24.87	3,141	135	1.03	.75	.791	.185	42	33
Results:											
10 best herds	10	136	27.20	5,358	285	2.00	27.20	.507	.096	10	0
10 poorest herds	10	123	26.00	2,265	89	.65	−9.10	1.14	.293	0	10
6 best dairy-type herds	6	88	27.00	5,637	303	2.15	31.05	.479	.089	6	0
6 best dual-purpose herds	6	82	32.50	5,316	234	1.36	11.86	.613	.139	6	0
Best single dairy-type herd	1	8	24.00	5,966	334	2.64	39.46	.402	.072	1	0
Best single dual-purpose herd	1	20	32.00	6,000	300	1.78	24.96	.533	.107	1	0

NOTES ON CANVASS NO. 2.

All the herds reporting a net loss are dual purpose, grade Shorthorn, or native.

All the silage feeders are also readers; two have dairy-type herds, one dual purpose.

Of the best 10 herds, 9 are of dairy type and 1 dual purpose; 5 owners read dairy literature, 3 say they do not, and the other 2 do not report on this point.

Of the poorest 10 herds, none are of dairy type, and only 2 owners read dairy literature.

Comparing the best six herds of dairy type with the best six dual-purpose herds, the figures show that if the owners of the 82 dual-purpose cows had fed the same feed, costing $2,665, all together to cows of dairy type, this feed would have fed 98 dairy cows, which would have returned a net profit of $3,042.90, over three times the amount of profit actually produced by the 82 dual-purpose cows, which was $972.52.

Or, the $972.52 net profit received from the 82 dual-purpose cows might have been earned by 32 dairy cows at an expense for feed of $864, less than one-third the feed bill of the 82 dual-purpose cows.

The dairyman who reads dairy literature secures nine times the net profit of the nonreader. By reference to the table it will be seen that those who read make 28 cents on the dollar net profit, while those who do not read make only 3 cents.

The ratio of profitable to unprofitable dairies is more than three times as great among the readers as among the nonreaders, which means that dairymen who read dairy literature stand more than three times as much chance of making a profit as those who do not read.[1]

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[1] The following explanation is offered of the manner of comparing ratios here and elsewhere in these pages: Among the herds belonging to men who read there are 20 profitable to 5 unprofitable. The ratio may be written in different ways, as 20 to 5, 20:5, or $\frac{20}{5}$, which equals 4 to 1.

On the other hand, among the herds belonging to men who do not read there are 42 profitable to 33 unprofitable. This ratio, like the other, may be written in different ways, as 42 to 33, 42:33, or $\frac{42}{33}$, which equals 1.27 to 1.

It will be seen that the former ratio is more than three times as great as the latter, indicating the proportion of readers who make a profit compared with the nonreaders who do so.

CANVASS NO. 3.

Conducted in Ohio, 1899–1900. Representing four creameries in five counties of eastern Ohio, George E. Scott, canvasser. 100 herds, 994 cows.

[Average price of milk, $1.05 per 100 pounds; average price of butter, 19.8 cents per pound.]

Comparisons.	Number of herds.	Number of cows.	Yearly cost of feed per cow.	Pounds of milk yearly per cow.	Pounds of butter yearly per cow.	Returns for $1 worth of feed.	Net profit per cow yearly.	Food cost of milk per 100 pounds.	Food cost of butter per pound.	Profitable herds.	Unprofitable herds.
Total of canvass	100	994	$26.58	4,048	214	$1.60	$15.94	$0.656	$0.124	97	3
Cows:											
Dairy type	39	418	27.05	4,548	249	1.88	23.80	.594	.108	39	0
Dual purpose	20	170	27.60	3,510	174	1.31	8.56	.786	.158	17	3
Feed:											
Silage fed	40	506	25.82	4,278	230	1.75	19.35	.603	.112	39	1
No silage	60	488	27.08	3,895	203	1.50	13.68	.695	.133	58	2
Stables:											
Good	50	535	26.92	4,447	237	1.78	21.00	.605	.114	50	0
Poor	15	117	26.47	3,274	168	1.29	7.68	.809	.157	13	2
Results:											
Best herds	15	163	25.00	4,680	259	2.14	28.50	.534	.097	15	0
Poorest herds	15	119	27.00	2,850	147	1.09	2.43	.968	.184	12	3

NOTES ON CANVASS NO. 3.

Only three herds of this canvass return less than the cost of feed. The average returns for $1 spent on feed are greater than in any other canvass, amounting to $1.61.

The average herd of this canvass is 10 cows. When of dairy type, this size herd returns $238 net profit. When of dual-purpose type, it returns $85.60, showing nearly three times the profit from dairy-type cows over dual purpose.

In this locality silage costs about $2 per ton for growing and storing. The silage feeders have the advantage over those not using silage in a reduced cost of $1.26 per cow, an increased net profit of $5.67 per cow, an increased production of milk of 383 pounds per cow, and an increased production of butter of 27 pounds per cow, producing milk at a food cost lower by 9.2 cents per 100 pounds and butter at a food cost lower by 2.1 cents per pound, and showing a return for each dollar spent in feed of 25 cents more than those who do not feed silage and a net profit 50 per cent greater.

The herds showing a combination of dairy type with silage feeding number 22, with 289 cows, and return $1.93 for each dollar spent in feed. On the other hand, the herds representing a combination of native blood without silage feeding number 17, with 129 cows, and for each dollar spent in feed they return $1.31, showing three times as much net profit from the better combination of breeding and feeding.

The best 15 herds return in each case an average profit of $2 or more for each dollar spent in feed. All of them are of dairy type; 12 of them are fed silage, 10 have good stables, 5 have fair stables.

The poorest 15 herds return in each case an average of $1.25 or less for each dollar spent in feed. Only 1 of these herds is of dairy type; 6 are grades of dairy breeds, but of poor type; 8 are of native or mixed breeds; 3 are fed silage; none have good stables, 8 have fair stables, 7 have poor stables.

CANVASS NO. 4.

Conducted in Delaware and Otsego Counties, N. Y., 1900. W. H. Jenkins, canvasser. 100 herds, 1,704 cows.

[Price of milk, 93 cents per 100 pounds; price of butter, 18 cents per pound.]

Comparisons.	Number of herds.	Number of cows.	Yearly cost of feed per cow.	Pounds of milk yearly per cow.	Pounds of butter yearly per cow.	Returns for $1 worth of feed.	Net profit per cow, yearly.	Food cost of milk per 100 pounds.	Food cost of butter per pound.	Profitable herds.	Unprofitable herds.
Total of canvass	100	1,704	$31.99	3,623	188	$1.05	$1.60	$0.883	$0.17	53	47
Cows:											
Dairy type	40	712	32.27	......	229	1.28	8.93	......	.141	37	3
Mixed breeds	50	801	31.54	......	158	0.89	−3.43	......	.20	10	40
Feed:											
Silage used	26	566	31.77	......	192	1.10	3.22	......	.165	14	12
Soiling crops fed	21	337	30.90	......	198	1.15	4.63	......	.156	15	6
Stables:											
Good	33	561	33.27	4,248	229	1.23	7.65	.783	.146	28	5
Fair	50	850	......	......	......	1.01	......	......	......	24	26
Poor	17	293	30.94	2,841	144	.82	−5.57	1.089	.215	1	16
Reading:											
Dairy literature	13	221	31.92	3,898	208	1.23	7.34	.819	.153	11	2
Agricultural literature	20	340	......	......	......	1.03	......	......	......	10	10
Nothing	67	1,143	31.66	3,506	180	1.03	0.95	.903	.176	32	35
Results:											
Best herds	10	140	34.60	......	294	1.52	17.99	......	.117	10	0
Poorest herds	10	140	33.80	......	132	.75	−8.32	......	.256	0	10
Best single herd	1	17	37.00	......	355	1.67	24.63	......	.107	1	0

NOTES ON CANVASS NO. 4.

These 100 herds are scattered among the valleys of the Delaware, Susquehanna, and Chenango Rivers, generally at some distance from the railroad in representative localities, but not in the best. A good ration here costs $35 to $40, divided as follows: Two tons hay, $20; ½ ton grain, $10; pasture, $5 to $10. This amount is reduced by soiling or feeding silage and by keeping the cows in warm stables.

The fact that a few men make a profit shows that it is possible when there is study and intelligent practice according to the successful methods pointed out in this canvass. Intelligence and character form the basis of success. Primitive methods are losing money. As a rule, those men are the most successful who read good dairy literature and attend farmers' institutes and other similar meetings.

Of the 40 dairy-type herds 11 are fed silage, 25 have good stables, 14 have fair stables, only 1 has a poor stable, 15 owners read, and 25 do not.

Of the 50 mixed herds 15 are fed silage, 7 have good stables, 27 have fair stables, 16 have poor stables, 12 of the owners read, and 38 do not.

A comparison of the dairy type and mixed herds shows a difference of $12.36 in net profit per cow in favor of the dairy type, and the food cost of butter for cows of the dairy type is only about 70 per cent as much as it is in the mixed herds. The reports are uncertain as to the type of 10 herds in this canvass.

Of the 26 silage-fed herds 9 have good stables, 14 have fair stables, 3 have poor stables, 11 owners read, and 15 owners do not.

The average profit from silage-fed herds is just twice the average profit in the whole canvass.

Of the 21 herds fed soiling crops 10 are of dairy type, 7 of mixed blood, and 4 uncertain; 8 have good stables, 10 have fair stables, and 3 have poor stables; 4 owners read dairy papers, 6 read agricultural papers, and 11 read none. Only 1 owner feeds silage in addition to soiling, but he receives $1.58 for each dollar spent in feed.

The average net profit of those who practice soiling is three times the average of the whole canvass.

Of the best 10 herds all return an average of $1.37 or more for each dollar spent in feed, all are of dairy type, 8 have good stables, 2 have fair stables, 4 are fed silage, 3 are fed soiling crops, 3 owners read dairy papers, 3 read agricultural papers, 4 read none.

Of the poorest 10 herds all lose an average of 25 cents on each dollar spent for feed, 1 herd is of dairy type, 1 has a good stable, 4 have fair stables, 5 have poor stables, none of the owners read dairy papers, 3 read agricultural papers, and 7 read none. One herd is fed silage and 1 is fed soiling crops.

The 8 herds showing the best combination of features produce an average of 231 pounds of butter and a return of $1.34 for each dollar's worth of feed, the lowest return from the cows of any herd in the group being $1.14 for each dollar's worth of feed. All these herds are of dairy type and have good stables, 6 are fed silage, 2 are fed soiling crops, and all the owners read dairy literature.

The best single herd is of dairy type, is kept in a good stable, and is fed soiling crops and purchased protein. Grain is fed 10 months of the year. The owner is a good judge of cows, is proud of his herd, and likes his business.

CANVASS NO. 5.

Conducted in Susquehanna County, Pa., 1901. W. H. Jenkins, canvasser. 50 herds, 663 cows.

[Average price of milk, $1.056 per hundred pounds.]

Comparisons.	Number of herds.	Number of cows.	Yearly cost of feed per cow.	Pounds of milk yearly per cow.	Returns for $1 worth of feed.	Net profit per cow yearly.	Food cost of milk per 100 pounds.	Profitable herds.	Unprofitable herds.
Total of canvass	50	663	$33.04	3,879	$1.26	$8.63	$0.852	39	11
Cows:									
Dairy type	15	235	33.08	5,007	1.63	20.85	.70	15	0
Not dairy type	21	265	32.00	3,296	1.05	1.70	.97	13	8
Feed:									
Silage	14	259	34.21	4,525	1.41	13.91	.756	12	2
No silage	36	404	33.14	3,696	1.18	6.04	.977	27	9
Stables:									
Good	13	173	34.62	5,041	1.56	19.39	.687	12	1
Fair	22	291	......	......	1.27	......	......	21	1
Poor	15	199	32.87	3,073	.98	−.66	1.07	6	9
Reading dairy literature:									
Readers	30	398	33.98	4,414	1.38	12.89	.769	27	3
Nonreaders	20	265	31.80	3,218	1.07	2.23	.988	12	8
Results:									
Most profitable herds	10	172	35.00	5,178	1.67	23.45	.675	10	0
Least profitable herds	10	149	33.21	2,614	.82	−5.98	1.27	0	10
Combination of features:									
Best combination	12	195	35.00	5,244	1.62	21.83	.667	12	0
Worst combination	8	112	33.00	2,798	.87	−4.20	1.215	1	7

NOTES ON CANVASS NO. 5.

All owners of dairy-type herds are readers, 12 have good stables, 3 have fair stables, 9 feed silage.

The type of 14 herds is not reported.

Of the owners of herds not of dairy type 5 feed silage, none have good stables, 11 have fair stables, and 10 poor stables; 8 read agricultural papers and 13 read nothing.

The average net profit of the dairy type herds is 12 times that of the scrubs.

Of the silage feeders all but 1 are readers, and that 1 receives but 57 cents for each dollar spent in feed. Nine of these herds are of dairy type and return an average of $1.63 for each dollar spent in feed. Five herds are not of dairy type and return $1.02 for each dollar spent in feed. Eight of the silage feeders have good stables, 4 have fair stables, and 2 have poor stables.

Of the herds fed no silage 6 are of dairy type and 16 are not of dairy type; of 14 the type is not reported. Seventeen owners read and 19 owners do not. Five have good stables, 18 have fair stables, 13 have poor stables. The silage feeders clear a net profit more than twice as great as that of the men who do not feed silage.

Of the 10 most profitable herds 8 are of dairy type, 2 are grades of dairy breeds, but of uncertain type. All the owners are readers, 6 feed silage, 8 have good stables, and 2 have fair stables.

All but 2 of the most profitable herds are in the group showing the best combination of features.

Of the owners of the 10 least profitable herds 2 are readers and 8 are not. None of the herds is of dairy type, 2 are fed silage, 1 has a good stable, 1 has a fair stable, and 8 have poor stables.

The best combination of features is where all have good stables, all the owners are readers, and all have dairy-bred herds. These number 12. Eight of these herds are fed silage. Comparing this group of 12 herds with the most profitable 10, we find the cost of feeding is the same. The food cost of milk is slightly less in the case of the best combination of features, but the net profit is greater in the 10 most profitable herds. The explanation of this apparent contradiction appears to be that in the case of the group showing greatest net profit the largest proportionate quantity of milk was produced in the winter when the price was high, while the food cost of milk is slightly less in the case of the herds producing relatively more of their milk during the summer time.

In the worst combination of features are included herds of scrub type, with poor stables, whose owners do not read. All but 1 of this group are in the group of the 10 herds making least profit.

The average net profit of dairymen who read is five times that of those who do not.

The average net profit of dairymen with good stables is twice that of those whose stables are only fair, while the ratio of profitable to unprofitable herds is 18 times as great among those having good stables as among those having poor stables.[1]

The canvasser calls attention to the following observations:

(1) This canvass of creamery patrons is fairly representative of the dairy industry in the State at the time.

(2) Only about one-half of the owners read any agricultural papers or use means for dairy education. Of this number less than half read dairy papers or literature.

(3) There is notable waste, especially through the feeding of poor cows.

(4) The principles of breeding are understood by very few. Less than 10 per cent keep good, pure-bred sires.

(5) The feeding of unbalanced rations is notable.

(6) Too much food is given for fuel instead of for milk. Three-fourths of the herds are not stabled with sufficient warmth.

(7) Not more than 10 per cent have stables sufficiently ventilated or lighted.

(8) Manure is wasted. Not more than 10 or 20 per cent have tight gutters with absorbents so as to save liquids, or spread manure daily on soil.

(9) Cornstalks are generally fed uncut and dry, only about one-half of which are actually eaten. The number of silos is increasing.

(10) None grow soiling crops for protein (alfalfa, peas, etc.).

(11) Much dissatisfaction, debt, and discouragement prevail.

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[1] For explanation in regard to comparison of ratios, see footnote to canvass 2, p. 14.

(12) In every locality there are a few progressive and prosperous dairymen. Note the range from returns of $70 per cow, with $1.75 for $1 in feed, down to $15 per cow, with $0.50 returned for every $1 in feed.

(13) To succeed, a dairyman must first see something in cows more than mere machines; then if he loves his business, his success is reasonably sure.

CANVASS NO. 6.

Conducted in Dunn County, Wis., 1901. C. P. Goodrich, canvasser. 52 herds, 647 cows.

[Average price of milk, 82.6 cents per 100 pounds; average price of butter, 17.8 cents per pound.]

Comparisons.	Number of herds.	Number of cows.	Yearly cost of feed per cow.	Pounds of milk yearly per cow.	Pounds of butter yearly per cow.	Returns for $1 worth of feed.	Net profit per cow yearly.	Food cost of milk per 100 pounds.	Food cost of butter per pound.	Profitable herds.	Unprofitable herds.
Total of canvass	52	647	$26.96	4,796	222	$1.47	$12.68	$0.562	$0.122	51	1
Cows:											
Dairy type	14	193	26.71	5,356	236	1.68	18.05	.491	.113	14	0
Not dairy type	30	344	27.06	4,382	197	1.34	9.27	.617	.137	29	1
Results:											
Most profitable herds	10	123	25.10	5,918	276	1.98	24.61	.424	.09	10	0
Least profitable herds	10	134	28.80	3,755	174	1.08	2.28	.767	.165	9	1

NOTES ON CANVASS NO. 6.

Eight herds of this canvass are of uncertain type.

Of the 52 herds, all but one make a profit, and that one returns 98 cents for each dollar spent on feed. The net profit per cow from the dairy type herds is double that from the scrubs. Of the 10 most profitable herds, 7 are of dairy type. Of the 10 least profitable herds, none are of dairy type.

CANVASS NO. 7.

Conducted in Onondaga County, N. Y., 1901-2. W. H. Jenkins, canvasser. 80 herds, 948 cows.

[Average price of milk, 89.3 cents per 100 pounds; average price of butter, 19.3 cents per pound.]

Comparisons.	Number of herds.	Number of cows.	Yearly cost of feed per cow.	Pounds of milk yearly per cow.	Pounds of butter yearly per cow.	Returns for $1 worth of feed.	Net profit per cow yearly.	Food cost of milk per 100 pounds.	Food cost of butter per pound.	Profitable herds.	Unprofitable herds.
Total of canvass	80	948	$30.07	3,981	184	$1.19	$5.79	$0.755	$0.163	54	26
Cows:											
Dairy type	20	235	28.00	5,044	245	1.67	18.76	.553	.114	20	0
Mixed herds	23	254	31.00	3,084	143	.87	− 3.87	1.005	.216	9	14
Feed:											
Alfalfa	40	594	28.83	4,214	201	1.35	10.05	.684	.143	31	9
Carbonaceous roughage	40	354	31.31	3,748	167	1.05	1.53	.835	.187	23	17
Stables:											
Good	11	132	30.73	5,071	244	1.63	19.36	.606	.126	11	0
Poor	33	396	30.53	3,488	162	1.10	3.05	.875	.188	16	17
Reading dairy literature:											
Owners read	26	308	32.04	4,645	216	1.39	12.50	.69	.149	20	6
Owners do not read	54	640	29.13	3,581	165	1.14	4.08	.813	.177	33	21
Results:											
Largest profits	10	109	26.50	5,544	256	1.97	25.75	.476	.103	10	0
Smallest profits	10	94	32.60	2,432	113	.63	−12.06	1.34	.288	0	10
Combination of features:											
Best combination	7	83	29.00	5,175	260	1.75	21.75	.56	.111	7	0
Worst combination	13	144	31.00	2,836	133	.82	− 5.58	1.09	.233	4	9

NOTES ON CANVASS No. 7.

This canvass makes prominent a comparison as to the economy of feeding between home-grown alfalfa and purchased protein. There are 40 herds of each class. The alfalfa growers feed little or no grain. The grain feeders use timothy hay and corn stover or silage for their winter roughage. Both classes have practically the same pasture.

The alfalfa growers secure an average net profit per cow per year $8.52 greater than that of the feeders of carbonaceous roughage. The ratio of profitable to unprofitable herds is 2½ times as great among the alfalfa feeders as it is among the feeders of carbonaceous roughage.[1]

Of the 10 herds showing largest profit, all but 2 are of dairy type. Five have good stables, 3 have fair stables, 2 have poor stables. Seven owners read; 3 do not.

Of the 10 herds showing least profit, all are of mixed breeding except 2, which are said to be grades, but are not of dairy type. All have poor stables except one, which is fair. Only one owner is a reader.

Most of the herds in this canvass are renewed by raising the heifers from the best cows. Fifteen herds in which the practice prevails of buying cows for building up the herd return an average for each dollar spent in feed of $1.08; the average return for the whole canvass being $1.19.

Herds in good stables return a net profit six times as great as those in poor stables.

The readers receive nearly three times the average net profit of the nonreaders, while the ratio of profitable to unprofitable herds among the readers (20:6) is more than twice as great as the corresponding ratio among the nonreaders (33:21).[1]

The group showing the best combination of features (herds of dairy type, stables good, owners readers) includes the herd showing largest yield of butter for the canvass, 355 pounds per cow, and the herd making the largest return for one dollar spent in feed, namely $2.19.

The 13 herds designated as having the worst combination of features are those consisting of scrub cattle, kept in poor stables, by owners who do not read. Under these conditions it costs twice as much to make a given quantity of milk or butter as under the conditions of the best combination of features.

Mr. W. H. Jenkins, who took this canvass, draws the following conclusions as to the principles of success in profitable dairy farming:

(1) Breed for the largest yield of butter fat.
(2) Feed a balanced and succulent ration, grown mostly on the farm.
(3) Use comfortable and sanitary stables.
(4) Spread all the manure on the soil without loss.

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[1] For explanation in regard to comparison of ratios, see footnote to canvass 2, p. 14.

CANVASS NO. 8.

Conducted in vicinity of Bainbridge, New York, 1901–2, among creamery patrons. H. H. Lyon, canvasser. 100 herds, 1,553 cows.

[Average price of milk, 99.5 cents per 100 pounds.]

Comparisons.	Number of herds.	Number of cows.	Yearly cost of feed per cow.	Pounds of milk yearly per cow.	Returns for $1 worth of feed.	Net profit per cow yearly.	Food cost of milk per 100 pounds.	Profitable herds.	Unprofitable herds.
Total of canvass	100	1,553	$38.10	3,908	$1.02	$0.89	$0.975	58	42
Cows:									
Dairy type	27	428	38.98	4,629	1.20	7.79	.842	25	2
Mixed type	12	185	36.43	3,116	.85	– 5.27	1.105	2	10
Feed: Silage fed	25	548	38.68	4,139	1.06	2.32	.935	15	10
Stables:									
Good	43	666	38.98	4,256	1.10	4.05	.914	28	15
Poor	25	387	35.76	3,255	.87	– 4.50	1.099	8	17
Reading:									
Dairy literature	7	108	41.00	5,366	1.39	15.99	.764	7	0
Agricultural literature	34	527	....	....	1.04	....	....	22	12
Nothing	44	682	37.61	3,546	.93	– 2.44	1.061	20	24
Results:									
Most profitable herds	10	146	38.30	5,389	1.43	16.66	.71	10	0
Least profitable herds	10	146	36.60	2,303	.60	–14.53	1.58	0	10
Combination of features:									
Best combination	5	97	38.00	5,350	1.40	15.20	.71	5	0
Poorest combination	4	42	36.50	3,099	.84	– 5.84	1.18	0	4

NOTES ON CANVASS NO. 8.

This canvass represents a territory supplying whole milk to creameries by weight.

The herd showing the largest percentage of profit returns $1.67 for each dollar spent in feed, is of dairy type, and has a good stable; the owner reads dairy literature and feeds silage.

It appears that large factors in success are the character of the cow, the owner's skill in selection, and the feed and care given.

The apparent needs of this territory are better and cheaper rations and better cows. There is no pure-bred herd in this canvass. Only two herds have pure-bred sires, and these were only recently placed in service.

Of the dairy type herds, 9 are fed silage, 14 have good stables, 12 have fair stables, and one has a poor stable; 17 owners read, and 7 do not.

Of the mixed herds, 2 are fed silage, 4 have good stables, 1 a fair stable, and 7 poor stables; 3 owners read, and 8 do not.

The dairy type herds return 35 cents more for each dollar's worth of feed than the mixed herds, the net profit being $13.06 greater. The type of 61 of the herds in this canvass is not reported.

Of the silage-fed herds, 9 are of dairy type, and 2 mixed, 14 being uncertain. Thirteen have good stables, 8 have fair stables, 4 have poor stables; 15 owners read, and 8 do not. The net profit of the silage-fed herds is 2½ times the average for the whole canvass.

The ratio of profitable to unprofitable herds is nearly three times (2.9) as great among the readers as among those who do not read.[1]

The ratio of profitable to unprofitable herds is four times as great with good stables as with poor stables.[1]

Of the 10 most profitable herds, 7 are of dairy type, 5 are fed silage, 7 have good stables, 2 have fair stables, 1 has a poor stable, and 9 owners read.

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[1] For explanation in regard to comparison of ratios see footnote to canvass 2, p. 14.

Of the 10 least profitable herds, 1 is composed of dairy grades; the others are mixed. Only 2 owners are readers, and they of agricultural, not dairy papers. Only 2 herds are fed silage; only 1 has a good stable, 3 have fair stables, and 6 have poor stables.

The least profitable herds average 14.6 cows to the herd. At the average loss of $14.53 per cow, the loss on each such herd amounts to $212.14 per year.

The best combination of features includes dairy type, silage feeding, good stables, and reading dairy or agricultural papers. The poorest combination of features includes scrub herds, poor stables, no silage, and no reading.

CANVASS NO. 9.

Conducted in Wisconsin, 1901–2, with creamery and cheese-factory patrons. C. P. Goodrich, canvasser. 60 herds, 809 cows.

[Average price of milk, 85.2 cents per 100 pounds; average price of butter, 19.3 cents per pound.]

Comparisons.	Number of herds.	Number of cows.	Yearly cost of feed per cow.	Pounds of milk yearly per cow.	Pounds of butter yearly per cow.	Returns for $1 worth of feed.	Net profit per cow yearly.	Food cost of milk per 100 pounds.	Food cost of butter per pound.	Profitable herds.	Unprofitable herds.
Total of canvass	60	809	$29.88	4,204	185	$1.20	$5.94	$0.71	$0.161	46	14
Cows:											
Dairy type	13	197	31.70	5,059	235	1.48	15.30	.626	.135	13	0
Mixed type	16	195	29.25	3,731	160	1.05	1.60	.784	.183	8	8
Best dairy type	1	25	28.00	5,809	298	2.04	29.18	.482	.094	1	0
Best beef type	1	7	29.00	3,266	152	.96	– 1.05	.887	.19	0	1
Feed: Silage used	6	111	31.50	5,928	260	1.68	21.42	.531	.121	6	0
Results:											
Most profitable herds	10	157	31.50	5,559	259	1.61	19.22	.568	.121	10	0
Least profitable herds	10	142	31.80	3,237	141	.85	– 4.84	.985	.225	0	10

NOTES ON CANVASS NO. 9.

The prices of feed given are: Timothy hay $12, mixed hay $8, corn stover $3, silage $2.50, oats $28, corn $21, wheat bran $19.50, gluten $24, malt sprouts $18.50, whole malt $30; pasture $5 for the season.

Of the 13 herds of dairy type, 6 use silage. Of the 16 herds of mixed breeding, none use silage. The herds of dairy type return a net profit nine times as great as that of mixed herds. The 6 herds using silage are all of dairy type.

Of the 10 most profitable herds, 8 are of dairy type, 2 are of dual-purpose breeding. All the herds which use silage are in this group also.

Of the 10 least profitable herds, none use silage; 2 are of dairy type, and 8 are of mixed breeding.

The best herd of dairy type consists of 25 Guernsey and Jersey cows. The ration fed includes bran and malt sprouts 6 pounds; silage 30 pounds; fodder corn in the fall; pasture only in the summer. The owner estimates that the added value of the skim milk brings his net profit up to $40.80 per cow per year.

The best herd of beef type consists of seven Durham grades. The ration is of malt sprouts and grain oats, 6 pounds corn stover, hay, and straw; pasture during summer. Adding the value of the skim milk to the creamery returns, we have a net profit of $5.48 per cow. The net profit of the best dairy-type herd, thus figured, is more than seven times that of the best beef-type herd.

Some further conclusions drawn from this canvass by the canvasser, Mr. C. P. Goodrich, are:

That heavy feeders, with good cows, stabled in comfort, make more profit than cheap feeders, relying on pasture for cows coming fresh in spring.

That the use of silage increases the quantity of milk about 12 per cent over dry feed of the same kind.

That the cheese factory paid its patrons 92 cents per 100 pounds for 4 per cent milk, while the creamery average for the same grade was 84 cents; this difference of 8 cents per 100 pounds may represent the difference in value between the skim milk and the whey.

CANVASS NO. 10.

Conducted in New York, 1901-2, among members of the Onondaga Milk Association.
W. H. Jenkins, canvasser. 45 herds, 1,022 cows.

[Average price of milk, $1.066 per 100 pounds.]

Comparisons.	Number of herds.	Number of cows.	Yearly cost of feed per cow.	Pounds of milk yearly per cow.	Returns for $1 worth of feed.	Net profit per cow yearly.	Food cost of milk per 100 pounds.	Profitable herds.	Unprofitable herds.
Total of canvass	45	1,022	$43.71	5,296	$1.30	$13.05	$0.825	34	11
Cows:									
Dairy type	8	166	45.26	6,923	1.67	30.32	.653	7	1
Scrub type	5	139	44.60	3,415	0.84	− 7.05	1.30	1	4
Feed: Silage feeders	14	389	42.43	4,968	1.26	10.96	.853	11	3
Stables:									
Good	36	817	43.89	5,998	1.35	15.30	.732	27	9
Poor	9	204	41.89	4,380	1.12	5.24	.956	7	2
Reading:									
Dairy literature	31	713	45.19	5,598	1.34	15.30	.807	24	7
Nothing	14	309	41.21	4,629	1.20	8.24	.89	11	3
Results:									
Most profitable herds	10	203	45.70	7,684	1.81	36.95	.594	10	0
Least profitable herds	10	260	47.90	3,457	.77	−11.06	1.385	0	10

NOTES ON CANVASS NO. 10.

This canvass shows great differences between the herds, due perhaps to the exceptional locality, near a large city (Syracuse). The average milk yield in this canvass is the largest of the whole series of canvasses, and the stables are unusually good. Winter dairying is most profitable. Alfalfa hay is the principal roughage and is fed with a moderate grain ration. The use of silage here is a rather perplexing factor, the results being somewhat contradictory. The alfalfa seems to be more significant than the silage. There is probably unusual force of individuality among the dairymen in this section.

Nearly every herd in this canvass is made up largely of grade Holsteins, with many high-grade and several pure-bred herds. The ratio of profitable to unprofitable herds is 28 times as great among the dairy-type herds as it is among the scrub herds.

Among the 10 most profitable herds, 5 are of dairy type and 5 are grades of dairy breeds, but of uncertain type. Nine of these herds have good stables, and 9 of the owners are readers.

Among the 10 least profitable herds, only 1 is of dairy type; 3 are dairy grades of uncertain type; 2 are of mixed breeding; and 4 are dairy grades of poor type. This group shows a very high cost of feed, resulting probably from feeding too much grain, while overlooking the great value of the alfalfa in the ration. Eight stables in this group are good, 2 are poor; 7 owners are readers.

The two men who are specially noted as great readers and students of dairying receive, respectively, $2.21 and $2.37 for each dollar spent in feed.

The average gain of those who read over those who do not read amounts to $7.06 per year for each cow.

The average gain of those who have good stables is three times that of those who have poor stables.

CANVASS NO. 11.

Conducted in Marshall County, Ind., 1902–3. C. P. Goodrich, canvasser. 50 herds. 282 cows.

[Average price of milk, 85 cents per 100 pounds; average price of butter fat, 19.4 cents per pound.]

Comparisons.	Number of herds.	Number of cows.	Yearly cost of feed per cow.	Pounds of milk yearly per cow.	Pounds of butter fat yearly per cow.	Returns for $1 worth of feed.	Net profit per cow yearly.	Food cost of milk per 100 pounds.	Food cost of butter fat per pound.	Profitable herds.	Unprofitable herds.
Total of canvass	50	282	$24.96	3,730	166.0	$1.26	$6.57	$0.668	$0.15	39	11
Cows:											
Dairy type	16	94	25.18	4,540	208.5	1.61	15.30	.554	.12	15	1
Scrub type	19	124	25.90	3,113	139.0	1.07	1.87	.832	.186	10	9
Feeding:											
Silage used	5	45	23.57	4,823	211.3	1.71	16.74	.503	.115	5	0
No silage	45	237	25.23	3,502	156.5	1.18	4.64	......	......	34	11
Reading:											
Dairy literature	6	34	24.06	4,133	181.0	1.46	11.07	.582	.133	6	0
Nothing	44	248	25.36	3,640	159.0	1.22	5.58	.691	.159	33	11
Results:											
Most profitable herds	10	67	24.40	5,138	229.0	1.82	20.00	.474	.106	10	0
Least profitable herds	10	76	26.80	2,561	120.0	.86	−3.72	1.046	.223	0	10

NOTES ON CANVASS NO. 11.

Prices of feed: Ground corn and oats $17 a ton, wheat bran $17, oil meal $30, corn in the ear $12, timothy hay $10, clover hay $8, corn stover $2 per load, silage $2 per ton, pasture $5 per head for the summer.

Quantity of feed: It is estimated that each cow eats during the winter 2 tons of hay or its equivalent in corn stover. Four or five loads of corn stover are estimated to furnish these 2 tons of forage when fed on the ground in the ordinary manner. Silage weighs 25 to 35 pounds to the bushel as taken from the silo.

The production of butter fat is given, instead of that of butter as in previous canvasses.

Herds of dairy type return over eight times the net profit of those of beef or scrub type.

Of the 10 most profitable herds, eight are of dairy type. Of the 10 least profitable herds, none are of dairy type.

The net returns from herds using silage are three times as great as those from the herds not using silage.

Owners who read dairy or agricultural papers receive twice the net profit of those who do not read.

Illustrations from records of single herds.

	Feed cost.		Returns per dollar.	Net profit.
No. 3, dairy type	$26.00	Ration, corn and clover	$1.61	$15.78
No. 4, beef type	25.00	Practically same ration	1.03	.89
No. 17, dairy grades	27.00	Good food, stable, and care	1.74	19.95
No. 7, dairy grades	18.50	Poor food, stable, and care	0.98	−.33
No. 21, mixed	22.00	Care excellent; regular	2.02	22.41
No. 23, mixed	20.00	Irregular; dairy a side issue	1.17	3.39
No. 29, dairy type	30.00	Good type, with silage	2.03	31.09
No. 19, beef type	20.50	Poor type, though profitable with silage	1.79	16.16
No. 42, dairy type	30.00	Owner student, balanced ration, good stable, and care.	1.54	16.16
No. 28, scrub type	23.00	Scrub farmer and poor feed	1.02	.48

CANVASS NO. 12.

Conducted in Geauga County, Ohio, 1908, among cheese-factory patrons. G. L. Poole, canvasser. 100 herds. 1,027 cows.

[Average price of milk, 88.9 cents per 100 pounds.]

Comparisons.	Number of herds.	Number of cows.	Yearly cost of feed per cow.	Pounds of milk yearly per cow.	Returns for $1 worth of feed.	Net profit per cow yearly.	Food cost of milk per 100 pounds.	Profitable herds.	Unprofitable herds.
Total of canvass	100	1,027	$28.20	4,547	$1.46	$13.02	$0.62	92	8
Cows:									
Dairy type	50	572	28.86	5,289	1.69	19.91	.545	49	1
Not dairy type	29	233	26.51	3,361	1.12	3.18	.785	22	7
Raise heifers	33	331	......	......	1.71	......	......	33	0
Feed: Use silage	15	241	31.06	5,501	1.71	22.05	.564	15	0
Stables:									
Excellent	16	162	30.35	5,270	1.60	18.21	.576	16	0
Good	15	151	......	......	1.53	......	......	14	1
Fair	31	312	......	......	1.46	......	......	30	1
Poor	33	334	26.81	3,954	1.35	9.38	.671	28	5
Reading:									
Dairy literature	22	221	29.45	5,585	1.75	22.09	.527	22	0
Agricultural literature	37	374	......	......	1.51	......	......	37	0
Nothing	24	243	26.54	3,567	1.19	5.04	.744	16	8
Results:									
Most profitable herds	10	127	30.25	6,830	2.15	34.80	.443	10	0
Least profitable herds	10	98	27.26	2,835	.90	−2.64	.961	2	8

NOTES ON CANVASS NO. 12.

Herds of dairy type return six times as much net profit per cow as those not of dairy type.

Twenty-six owners who raise heifers from herds of dairy type receive for each dollar invested in feed $1.80. Seven owners who raise heifers from herds not of dairy type receive for each dollar invested in feed $1.34.

Every silage feeder makes a profit.

The character of the stable is a fair index to the profit from the herd.

Readers of dairy literature receive four times the net profit of those who do not read. The net profit of readers of general agricultural papers is only slightly above the average for the whole canvass.

Of the 10 most profitable herds, all are of dairy type, 9 owners read, 9 raise heifers, 4 feed silage, 2 have excellent stables, 3 have good stables, 4 fair stables, and 1 a poor stable.

Of the 10 least profitable herds, only 1 is of dairy type, 1 owner reads an agricultural paper, none feed silage, 1 raises heifers, 1 stable is excellent, 2 are good, 2 fair, and 5 poor.

The best combination of features is found in a group of five herds returning for each dollar spent in feed $2.06. In this group all are of dairy type, all owners read, all feed silage, all raise heifers, all have excellent stables.

Conclusions by the canvasser:

Some men get better profit than others with the same kind of cows and feed.

What pays?

Answer: Comfortable stables, persistent milkers, careful attention, silage, and feed rich in protein.

CANVASS NO. 13.

Conducted in Lorain and Medina Counties, Ohio, 1904. G. L. Poole, canvasser. 87 herds, 635 cows.

[Average price of milk 77.3 cents per 100 pounds. Average price of butter, 15.1 cents per pound.]

Comparisons.	Number of herds.	Number of cows.	Yearly cost of feed per cow.	Pounds of milk yearly per cow.	Pounds of butter yearly per cow.	Returns for $1 worth of feed.	Net profit per cow yearly.	Food cost of milk per 100 pounds.	Food cost of butter per pound.	Profitable herds.	Unprofitable herds.
Total of canvass	87	635	$26.98	3,858	195	$1.10	$2.80	$0.70	$0.14	55	32
Cows:											
Dairy type	29	244	27.29	4,374	235	1.30	8.10	.624	.12	23	6
Not dairy type	34	217	26.88	3,380	165	.92	−2.10	.792	.162	14	20
Raise heifers	41	299				1.14				27	14
Feed: Silage fed	8	95	27.00	4,596	251	1.42	11.51	.587	.107	7	1
Stables:											
Excellent	3	22	27.33	4,704	279	1.61	16.67	.581	.098	3	0
Good	20	149				1.12				12	8
Fair	20	146				1.11				12	8
Poor	40	291	25.91	3,488	178	1.08	1.995	.743	.145	25	15
Reading:											
Dairy literature	2	15	28.00	4,736	293	1.71	20.02	.591	.096	2	0
Agricultural literature	45	328				1.11				27	18
Nothing	31	226	26.48	3,524	179	1.05	1.245	.751	.148	19	12
Results:											
Most profitable herds	10	74	26.74	4,884	281	1.66	17.75	.547	.096	10	0
Least profitable herds	10	83	28.20	2,845	136	0.71	−8.22	.991	.208	0	10

NOTES ON CANVASS NO. 13.

The ratio of profitable to unprofitable herds is 5½ times as great among herds of dairy type as it is among herds lacking dairy type.[1] The type of 24 herds in the canvass appears to be uncertain. The foundation stock in many herds was largely Durham. Upon this the Holstein-Friesian was crossed in order to increase the quantity of milk produced. Then the Jersey cross was used to enrich the quality of the milk. The results are generally failures as milk producers.

The profit of raising heifers rather than buying cows to renew the herd appears to depend largely upon the type of animals from which the heifers are bred. The ratio of profitable to unprofitable herds is seven times as great among the men who raise heifers from cows of dairy type as it is among those who raise heifers from cows lacking dairy type.[1]

The only silage feeder who fails to make a profit feeds cows of mixed breeding and not of dairy type.

Of the 10 most profitable herds, 8 are of dairy type, 4 use silage, 9 owners read agricultural literature (of whom 2 read dairy literature), 5 have good stables, 2 excellent stables, 2 fair stables, and 1 a poor stable; 5 raise heifers.

Of the 10 least profitable herds, 3 are of dairy type, 1 uses silage, 7 owners read agricultural literature, 5 have good stables, 1 fair, and 4 poor, and 4 raise heifers.

Reading agricultural papers which are not specially dairy papers does not seem to bring very much more profit than reading no papers at all.

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[1] For explanation in regard to comparison of ratios see footnote to canvass 2, p. 14.

CANVASS NO. 14.

Conducted in Wayne and Franklin Counties, Pa., 1904. Nathan Jenkins, canvasser.
99 herds, 858 cows.

[Average price of milk, 84 cents per 100 pounds; average price of butter, 18 cents per pound.]

Comparisons.	Number of herds.	Number of cows.	Yearly cost of feed per cow.	Pounds of milk yearly per cow.	Pounds of butter yearly per cow.	Returns for $1 worth of feed.	Net profit per cow yearly.	Feed cost of milk per 100 pounds.	Feed cost of butter per pound.	Profitable herds.	Unprofitable herds.
Total of canvass	99	858	$29.44	3,250	153	$0.94	—$1.85	$0.90	$0.192	39	60
Cows:											
Dairy type	10	78	30.86	4,508	214	1.32	9.83	.68	.144	10	0
Scrub herds	8	59	31.96	2,494	114	.62	—12.08	1.28	.279	0	8
Feed: Silage	2	27	30.79	4,338	204	1.36	11.08	.71	.15	2	0
Stables:											
Excellent	2	16	30.64	3,825	181	1.12	3.68	.801	.169	2	0
Good	9	100	......	......	......	.98	......	......	......	4	5
Fair	25	264	......	......	......	1.01	......	......	......	9	16
Poor	5	28	32.20	3,218	152	.80	— 6.44	1.001	.212	1	4
Reading:											
Dairy literature	12	122	30.17	3,850	179	1.10	3.02	.784	.169	8	4
Agricultural literature	27	217	......	......	......	.99	......	......	......	15	12
Nothing	51	433	29.74	3,027	142	.88	— 3.57	.982	.21	15	36
Results:											
Most profitable herds	10	65	29.90	4,384	205	1.36	10.90	.68	.145	10	0
Least profitable herds	10	92	32.83	2,384	109	.55	—14.70	1.37	.301	0	10
Largest profit	1	10	32.58	4,854	236	1.50	16.21	.67	.14	1	0
Greatest loss	1	22	31.00	1,283	88	.42	—17.91	2.42	.35	0	1

NOTES ON CANVASS NO. 14.

The first 40 herds of this canvass, in Wayne County, show poor cows, poor care, poor feed, and owners read little.

The next 59 herds are in Franklin County, in the Cumberland Valley, near the Maryland line. Nearly all the land is tillable. The usual rotation is corn, wheat, and grass. The common barn has basement with brick or stone wall, the second story projecting 6 feet or more on one side, with a driveway to second floor on opposite side. Stalls on cross lines. Windows and doors under projections. No basement floor; straw for bedding. Manure accumulates until corn-planting time. Dairying is not chief source of income.

Four herds make a net profit of $10 per cow or more; 10 herds make a net loss of $10 per cow or more; 19 herds make a net profit of $5 per cow or more; 31 herds make a net loss of $5 per cow or more; 16 herds make a butter average of 200 pounds or more; 83 herds make a butter average less than 200 pounds.

Only 18 herds in this canvass are so reported as to make clear whether they are of dairy type or not. The cost of producing milk and butter is nearly twice as great with scrubs as with cows of dairy type. The average net profit for cows is $21.91 greater with cows of dairy type than with scrubs.

Of the 10 owners of herds of dairy type 3 read dairy papers, 6 read agricultural papers, and 1 does not read. One of these owners has an excellent stable, 2 have good stables, 4 have fair stables, and 1 has a poor stable.

Of the 8 owners of scrub herds, none read dairy papers, 3 read agricultural papers, and 3 read none (2 not reporting on this point). None of this group are reported as having either good or excellent stables.

Only 2 herds in this canvass are fed silage.

The character of the stabling is reported for only 41 herds in this canvass.

Of the 10 most profitable herds, 7 are of dairy type and 3 of uncertain type; 4 owners read dairy papers, 3 read agricultural papers, 2 read none, and 1 is not reported as to reading. One of the group has a good stable, and 7 have fair stables.

Of the 10 least profitable herds, none are of dairy type, 6 are of scrub type, and 4 are of uncertain type. None of the owners in this group read dairy papers, 3 read agricultural papers, and 6 read none. No stables in this group are reported as either excellent or good.

The largest profit comes to a man who feeds silage, reads dairy literature, has dairy type cattle, raises heifers, and has fair stables.

The greatest loss is in a herd of mixed grades, whose owner does not read and puts other business first.

The ratio of profitable to unprofitable herds is nearly five (4.8) times as great among readers of dairy papers as it is among those who do not read.[1] No report is given as to the reading of 9 owners.

CANVASS NO. 15.

Conducted in vicinity of Andover, Conn., 1904, among coöperative cream-gathering patrons. H. H. Lyon, canvasser. 50 herds, 445 cows.

[Average price of butter fat, 26.98 cents per pound.]

Comparisons.	Number of herds.	Number of cows.	Yearly cost of feed per cow.	Pounds of butter fat yearly per cow.	Returns for $1 worth of feed.	Net profit per cow yearly.	Food cost of butter fat per pound.	Profitable herds.	Unprofitable herds.
Total of canvass	50	445	$37.02	138.2	$1.004	$0.13	$0.268	24	26
Cows: Dairy type	7	88	38.25	161.9	1.18	6.91	.236	5	2
Feed: Silage	1	14	38.75	191.3	1.44	17.19	.203	1	0
Stables:									
Good	3	55	37.63	157.8	1.28	10.54	.238	3	0
Fair	16	155	......	......	1.02	......	......	11	5
Poor	6	46	36.50	111.8	.79	−7.66	.326	0	6
Reading:									
Dairy literature	6	83	38.60	182.0	1.31	11.97	.212	6	0
Agricultural literature	29	248	......	......	.97	......	......	13	16
Nothing	11	72	36.09	123.0	.89	−3.97	.293	3	8
Results:									
Most profitable herds	5	53	38.67	201.2	1.41	15.95	.192	5	0
Least profitable herds	5	33	36.87	109.1	.75	−9.37	.337	0	5

NOTES ON CANVASS NO. 15.

Prices of feed: Pasturage $5 per season; bran $22 per ton; hay $12 per ton; cottonseed meal $30 per ton; corn fodder $6 per ton; silage $3 per ton.

Of the 7 owners of herds of dairy type, all are readers; 3 read dairy papers and 4 read agricultural papers. Two of this group have good stables, 2 have fair stables, and 1 has a poor stable.

The ratio of profitable to unprofitable herds is nearly three (2.7) times as great among the herds of dairy type as it is throughout the canvass as a whole.[1]

The one silage feeder has a herd of dairy type, reads dairy papers and has a fair stable.

Of the most profitable herds, all are grades of dairy breeds; 3 owners read dairy literature, 1 has a good stable, 3 have fair stables.

Of the least profitable herds, none are of good dairy type; 3 owners read agricultural literature, 2 read nothing, 3 have poor stables, 1 has a fair stable.

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[1] See footnote to canvass 2, p. 14, for explanation as to comparison of ratios.

The man who makes the largest profit has a herd of 16 grades of dairy type, producing an average of 215 pounds of butter fat, returning for each dollar spent in feed $1.52 and a net profit per cow of $22.12. He has a good stable and reads dairy papers.

The readers of dairy papers receive for each dollar spent for feed $0.42 more than the men who do not read.

CANVASS NO. 16.

Conducted in central and northern portions of Vermont, 1904, among patrons of four creameries. H. H. Lyon, canvasser. 100 herds, 1,914 cows.

[Average price of butter fat per pound, 22.25 cents.]

Comparisons.	Number of herds.	Number of cows.	Yearly cost of feed per cow.	Pounds of butter fat yearly per cow.	Returns for $1 worth of feed.	Net profit per cow yearly.	Food cost of butter fat per pound.	Profitable herds.	Unprofitable herds.
Total of canvass	100	1,914	$36.57	150.5	$0.91	−$3.20	$0.242	32	68
Cows: Dairy type	12	354	37.21	207.5	1.32	11.90	.179	11	1
Feed: Silage	19	642	36.05	160.9	1.04	1.55	.224	12	7
Stables:									
Excellent	6	215	36.91	177.2	1.38	14.03	.208	6	0
Good	8	261	......	......	1.18	......	......	7	1
Fair	22	419	......	......	.94	......	......	7	15
Poor	15	214	36.53	123.2	.73	− 9.86	.297	0	15
Reading:									
Dairy literature	11	189	37.36	205.1	1.25	9.34	.182	10	1
Agricultural literature	34	553	......	......	.91	......	......	11	23
Nothing	38	658	36.00	134.6	.80	− 7.20	.267	5	33
Results:									
Most profitable herds	10	243	38.37	231.2	1.39	15.15	.166	10	0
Least profitable herds	10	146	36.75	92.8	.54	−16.90	.40	0	10

NOTES ON CANVASS NO. 16.

Prices of feed: Pasture $5 per season; hay $12 a ton; silage $3 a ton; bran $21 a ton; corn meal $22 a ton; cottonseed meal $30 a ton; linseed meal $30 a ton; gluten meal $24 a ton.

Of the 12 owners of dairy type herds, 7 feed silage, 6 read dairy papers, 1 reads general farm papers, 1 reads none, and 4 are not reported as to reading. Of this group, 5 have excellent stables, 3 have good stables, and 4 are not reported as to stables.

Herds of dairy type return for each dollar's worth of feed 41 cents more than the average of the whole canvass.

Of the 6 owners of excellent stables, all have herds of dairy type except 1, and that herd is of grades of a dairy breed; 3 use silage, 3 read dairy papers, 1 reads a farm paper, and 2 are not reported as to reading.

Of the 8 owners of good stables, 3 have herds of dairy type, 5 feed silage, 4 read dairy papers, 2 read farm papers, 1 reads nothing, and 1 is not reported as to reading.

Of the 11 readers of dairy papers, 6 have herds of dairy type, 3 feed silage, 3 have excellent stables, 4 have good stables, 1 has a fair stable, and 3 are not reported as to stabling.

Men who read dairy literature earn with each dollar spent in feed 45 cents more than men who do not read.

Of the 10 most profitable herds, all are grades of dairy breeds, 8 are of good dairy type; 4 owners feed silage, 6 read dairy literature, 4 have excellent stables, 4 have good stables.

Of the 10 least profitable herds, none are of good dairy type, 6 are grades of dairy breeds, 4 are of mixed breeding; only 1 owner reads agricultural literature, 7 owners read nothing; 1 feeds silage, 4 have poor stables, and the stabling of 6 is not reported.

Seven herds average $10 or more profit per cow per year. All these are of dairy type, 3 are fed silage, 4 have excellent stables, 4 owners read dairy literature.

Twenty-one herds lose an average of $10 or more per cow per year. Only 1 of these herds is fed silage, none are of dairy type, none of their owners read dairy literature. Five read agricultural papers, 13 read neither dairy nor agricultural papers; none have either excellent or good stables, 1 has a fair stable, 7 have poor stables.

The man who secures only the average returns has a herd of uncertain type, reads general farm papers (not dairy papers), and has only a fair stable.

CANVASS NO. 17.

Conducted in Minnesota, 1904, among creamery patrons. Frank Kinsley, canvasser. 100 herds, 1,092 cows.

[Average price of butter fat per pound, 21.1 cents.]

Comparisons.	Number of herds.	Number of cows.	Yearly cost of feed per cow.	Pounds of butter fat yearly per cow.	Returns for $1 worth of feed.	Net profit per cow yearly.	Food cost of butter fat per pound.	Profitable herds.	Unprofitable herds.
Total of canvass	100	1,092	$24.90	142.4	$1.21	$5.15	$0.175	66	34
Cows: Dairy type	14	155	28.02	219.8	1.65	18.13	.128	14	0
Feed: Silage	3	40	29.12	275.0	1.80	23.36	.106	3	0
Stables:									
Good	57	560	24.39	156.0	1.20	4.93	.163	41	16
Fair	28	275	....	....	1.14	....	....	17	11
Poor	15	156	23.40	114.2	1.01	.19	.206	8	7
Reading:									
Dairy literature	65	638	25.52	173.0	1.36	9.26	.147	60	5
Nothing	35	353	23.80	99.2	.86	−3.21	.24	6	29
Results:									
Most profitable herds	10	129	29.54	258.0	1.83	24.66	.115	10	0
Least profitable herds	10	103	24.65	82.2	.70	−7.40	.30	0	10

NOTES ON CANVASS NO. 17.

Prices of feed: Corn $13 per ton; oats $15 per ton; bran $16 per ton; silage $1 per ton; hay $5 per ton; fodder corn $4 per ton; oil cake $26 per ton; pasture (7 months) $6 per cow. Of these herds, 24 show a profit of $10 or more per cow per year.

The greatest gain is in a herd of natives, producing 313.5 pounds of fat per cow, returning $2.35 for each dollar spent in feed, and a net gain of $37.85 per cow per year. The owner has a good stable and reads dairy literature.

The greatest loss is $10.51 per cow per year, in a herd of Shorthorns producing an average of 69 pounds of fat per cow. The owner has a poor stable and does not read.

Of the 14 owners of herds of dairy type, all read dairy literature, 10 have good stables, 4 have fair stables, 2 feed silage. The average net profit among herds of dairy type is 3½ times the average for the whole canvass.

Of the 3 owners who feed silage, 2 have herds of dairy type, all read dairy literature, 2 have good stables, and 1 has a fair stable. The average net profit of the silage feeders is 4½ times the average for the whole canvass.

The ratio of profitable to unprofitable herds is 58 times as great among the readers of dairy literature as it is among those who do not read.[1]

Of the 10 most profitable herds, 7 are of dairy type, 2 are fed silage, all the owners read dairy papers, 8 have good stables, and 2 have fair stables.

Of the 10 least profitable herds, none are of dairy type, none use silage, 1 owner reads, 5 have good stables, 2 have fair stables, and 3 have poor stables.

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[1] See footnote to canvass 2, p. 14, for explanation as to comparison of ratios.

CANVASS NO. 18.

Conducted in Waukesha County, Wis., 1905, among patrons of Wales Creamery. C. P. Goodrich, canvasser. 40 herds, 556 cows.

[Average price of butter per pound, 20.4 cents.]

Comparisons.	Number of herds.	Number of cows.	Yearly cost of feed per cow.	Pounds of butter yearly per cow.	Returns for $1 worth of feed.	Net profit per cow yearly.	Food cost of butter per pound.	Profitable herds.	Unprofitable herds.
Total of canvass	40	556	$30.00	202	$1.38	$11.29	$0.148	38	2
Cows:									
Dairy type	17	203	30.16	244	1.69	20.81	.124	17	0
Scrub type	9	150	29.89	159	1.07	2.09	.188	7	2
Fresh in fall	2	25	37.50	244	1.40	15.14	.113	....	....
Fresh in spring	2	27	23.75	156	1.26	6.32	.152	....	....
Reading:									
Dairy literature	7	98	29.96	254	1.73	21.87	.118	7	0
Agricultural literature	8	112	....	....	1.36	10.94	....	....	....
Nothing	25	346	29.83	190	1.30	8.95	.157	23	2
Results:									
Best herds	8	104	29.75	274	1.91	27.06	.108	8	0
Poorest herds	8	127	31.81	161	1.02	.63	.198	6	2
Herd making largest returns per cow	1	16	34.00	315	1.97	32.89	.108	1	0
Herd making smallest returns per cow	1	25	26.00	117	.88	−3.08	.222	0	1
Herd making largest returns for feed	1	12	25.00	257	2.15	28.71	.097	1	0
Herd making smallest returns for feed	1	13	32.00	130	.85	−4.67	.246	0	1

NOTES ON CANVASS NO. 18.

Prices of feed: Pasture $5 per season; timothy hay $8 per ton; clover hay $6 per ton; marsh hay $5 per ton; silage $2.50 per ton; corn stover $2.50 per ton; oats ground, $21.50 per ton; ear corn $12 per ton; corn, shelled and ground, $16 per ton; bran $18 per ton; middlings $20 per ton.

Only two herds in this canvass are kept at a loss.

Herds of dairy type earn 10 times the net profit of the scrubs.

The largest returns per cow are in a herd of good dairy type coming fresh in the fall and winter, fed clover hay and shredded fodder, with bran and middlings, and with an owner who studies dairy literature.

The smallest returns per cow are in a herd of scrubs coming fresh in winter and spring, fed hay and stover, corn and oats.

The largest returns for a dollar's worth of feed are in a herd of good dairy type, fresh in fall and spring, fed clover and timothy, corn fodder, silage, and bran, and whose owner studies.

The smallest returns for a dollar's worth of feed are in a herd of scrubs, fresh in fall, fed hay and stover, bran and middlings, but fed too little when fresh in the fall, so that they can not bring back their lost flow on spring pasture.

The cows fresh in the fall which are given a heavy grain feed while fresh, and whose butter sells at a comparatively high price in the winter, make a better showing than the cows which come fresh in the spring and are fed no grain; the former show $8.82 higher net profit, and 14 cents higher return on each dollar's worth of feed given.

The seven readers of dairy literature receive a net profit per cow per year of $12.92 more than the owners who do not read. For the average herd of 14 cows this means $180.88 added to the owner's profit for studying his own business.

CANVASS NO. 19.

Conducted in Delaware County, N. Y., 1904–5. Nathan Jenkins, canvasser. 100 herds, 2,408 cows.

Of these herds, 50 supply a cooperative creamery, and the other 50 supply Borden's condensed-milk factory.

[Average price of milk for the canvass, $1.334 per 100 pounds; average price of milk at cooperative creamery, $1.38 per 100 pounds; average price of milk at Borden's, $1.262 per 100 pounds; average price of butter fat per pound, 28.8 cents.]

Comparisons.	Number of herds.	Number of cows.	Yearly cost of feed per cow.	Pounds of milk yearly per cow.	Pounds of butter fat yearly per cow.	Returns for $1 worth of feed.	Net profit per cow yearly.	Food cost of milk per 100 pounds.	Food cost of butter fat per pound.	Profitable herds.	Unprofitable herds.
Total of canvass	100	2,408	$38.69	4,083	186.4	$1.44	$17.25	$0.947	$0.205	97	3
Selling to creamery	50	1,413	38.29	3,828	186.4	1.42	16.15	1.00	.205	47	3
Selling to Borden	50	995	39.16	4,524	....	1.46	18.26	.865	....	50	0
Cows:											
Dairy type	26	826	39.26	....	199.3	1.53	20.81	....	.197	25	1
Not dairy type	15	340	34.66	....	162.4	1.30	10.50	....	.213	13	2
Feed: Silage	12	382	40.12	4,026	194.2	1.44	17.73	.996	.206	12	0
Stables:											
Excellent	53	1,403	40.12	4,160	206.1	1.50	20.06	.964	.195	53	0
Good	29	647	....	....	....	1.44	....	....	....	....	....
Fair	5	100	....	....	....	1.49	....	....	....	....	....
Poor	13	258	36.55	3,296	143.0	1.15	5.48	1.109	.255	10	3
Reading:											
Dairy literature	18	549	39.88	4,162	202.1	1.50	19.94	.958	.148	18	0
Agricultural literature	49	1,200	....	....	....	1.47	....	....	....	....	....
Nothing	33	659	38.37	3,718	174.0	1.34	13.05	1.082	.22	31	2
Results:											
Best herds	10	277	40.64	5,128	260.0	1.86	34.93	.792	.156	10	0
Poorest herds	10	208	36.17	2,734	132.6	1.00	.07	1.32	.272	7	3

NOTES ON CANVASS NO. 19.

Borden's prices for milk ranged from 90 cents in June to $1.65 in December, favoring milk of low butter-fat content, prohibiting silage and distillers' grains.

The 26 herds of dairy type have pure-bred bulls and raised their heifers. The 15 herds not of dairy type use grade bulls. The dairy type cows return twice as much net profit as the scrubs.

Forty-three herds show a profit per cow per year of over $20. The 10 best herds show a profit per cow per year of over $33. Only 3 herds show an actual loss.

Of the 10 best herds, 7 are of dairy type, and the other 3 are grades of dairy breeds. Nine owners in this class read dairy literature, 8 have excellent stables, and 2 have good stables.

Of the 10 poorest herds, only 3 are of dairy type; only 3 owners read; 6 have poor stables.

Of the 3 herds showing an actual loss, all have poor stables, 2 use grade bulls; and only 1 owner reads.

The neglect of reading in this canvass means the loss of one-third of the net profit received by readers of dairy literature.

Excellent stables show more than three times the net profit of poor stables in this canvass.

CANVASS NO. 20.[1]

Conducted in Butler and Jackson Counties, Mich., 1905, among creamery patrons.
M. W. Clark, canvasser. 100 herds, 849 cows.

[Average price of milk per 100 pounds, $1.01; average price of butter fat, 23.25 cents; average butter-fat test, 4.37 per cent.]

Comparisons.	Number of herds.	Number of cows.	Yearly cost of feed per cow.	Pounds of milk yearly per cow.	Pounds of butter fat yearly per cow.	Returns for $1 worth of feed.	Net profit per cow yearly.	Food cost of milk per 100 pounds.	Food cost of butter fat per pound.	Profitable herds.	Unprofitable herds.
Total of canvass	100	849	$32.12	4,093	177.4	$1.25	$8.14	$0.784	$0.181	78	22
Cows:											
Dairy type	10	130	24.77	4,430	204.0	1.96	23.82	.559	.121	10	0
Scrub type	10	69	38.57	3,542	158.5	1.01	.39	1.088	.243	5	5
Feed:											
Dry fed—											
Fed dry fodder	82	620	35.44	3,971	174.0	1.11	3.91	.892	.204	61	21
Most profitable herds of those fed dry fodder	20	127	31.85	4,606	....	1.56	17.73	.691	....	20	0
Most profitable dry-fed herds fresh in spring	5	30	28.67	4,877	....	1.66	18.96	.587	....	5	0
Most profitable dry-fed herds fresh in fall	5	34	30.10	4,020	....	1.37	11.23	.771	....	5	0
Unprofitable dry-fed herds	10	90	43.40	2,997	....	.63	−15.83	1.45	....	0	10
Silage fed—											
Fed on silage	18	229	27.79	4,398	192.2	1.66	18.28	.631	.145	17	1
Best herds silage fed[2]	10	150	25.44	4,894	....	2.01	25.76	.52	....	10	0
Pure-bred, silage fed, fresh in spring[3]	3	59	23.15	4,452	....	2.21	27.96	.52	....	3	0
Best grades, fresh in fall, fed silage and grain[4]	3	47	35.67	4,989	....	1.38	13.77	.715	....	3	0
Grades fresh in spring, fed silage without grain[5]	2	19	19.63	4,872	....	2.36	26.82	.402	....	2	0
Poorest silage fed	3	49	32.54	3,762	....	1.14	4.54	.864	....	2	1
Stables:											
Excellent	11	151	27.10	4,749	206.0	1.98	21.84	.571	.131	11	0
Good	27	208				1.68				27	0
Fair	39	313	....	....	....	1.08	....	....	....	29	10
Poor	23	177	41.21	3,960	173.0	.97	− 1.24	1.04	.238	9	14
Reading:											
Dairy literature	37	358	32.21	4,432	193.0	1.39	12.56	.726	.167	31	6
Agricultural literature	28	227	....	....	....	1.37	....	....	....	22	6
Nothing	30	225	33.00	3,888	168.0	1.19	6.27	.849	.196	20	10
Results:											
Most profitable herds	10	96	27.30	5,434	237.7	2.11	29.94	.504	.115	10	0
Least profitable herds	10	84	43.75	2,952	118.5	.62	−16.60	1.48	.37	0	10

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[1] Special attention was given in this canvass to the relative advantages of silage and dry fodder.
[2] Compare with 20 best dry fed.
[3] Compare with 5 best dry fed, fresh in spring.
[4] Compare with 5 best dry fed, fresh in fall.
[5] Compare with dry fed, fresh in spring.

NOTES ON CANVASS NO. 20.

Stables excellent and good are averaged together. The combined average return for one dollar's worth of feed is $1.81.

Of the entire canvass, 65 herds (505 cows) are Durhams and Durham grades, and of this group 72 per cent earn a profit, while 28 per cent make a loss. Thirty-five of the 100 herds (344 cows) are Jersey and Jersey grades, and of these 81.6 per cent return a profit, while 18.4 per cent make a loss. The averages for these two groups are not available. The 10 herds designated in the table as dairy type are all headed by pure-bred bulls of dairy breeds; the 10 herds designated as scrub type are headed by grade bulls. While owners of herds of good dairy type receive nearly $2 for each $1 spent in feed, the owners of scrubs barely get their money back.

Comparison of dry-fed with silage-fed herds is favorable to silage by $7.65 less cost of feed per cow, by 427 pounds more milk, by 18.2 pounds more butter fat, by $0.55 more returned for each $1 spent for feed, by $14.37 more net returns per cow, by $0.261 per 100 pounds less food cost of milk, and by $0.059 per pound less food cost of butter fat.

Of the 18 silage-fed herds, 7 are of good dairy type, none are of scrub type, 9 have excellent stables, 5 have good stables, 4 have fair stables, 10 owners read dairy papers, 5 read farm papers, 3 read none.

Of the 82 dry-fed herds, 3 are of good dairy type, 10 are of scrub type, 2 have excellent stables, 22 have good stables, 35 have fair stables; all the poor stables in the canvass (23) are in this group; 27 owners read dairy papers, 23 read farm papers, 27 read none.

Of the 10 most profitable herds, 5 are of dairy type, 4 are fed silage, 5 have excellent stables, and 8 owners read dairy literature.

Of the 10 least profitable herds, 6 are scrub, none are fed silage, 7 have poor stables, and only 2 of the owners are readers.

The better half of all these 100 herds average a net gain of $19.05 per cow per year, ranging from $7.82 to $34.27.

The poorer half average a net loss of $3.24 per cow per year, ranging from a gain of $7.80 to a loss of $28.90.

All of the most successful dairymen who are owners or managers read dairy literature. Only 6 of the 22 losing herds are owned by readers of dairy papers.

The ratio of profitable to unprofitable herds is more than 2½ times as great among the readers of dairy papers as it is among those who do not read.[1]

CANVASS NO. 21.

Conducted in vicinity of Ellisburg, Jefferson County, N. Y., 1906. T. H. Staplin, canvasser. 100 herds, 1,843 cows.

[Average price of milk per 100 pounds, $1.13.]

Comparisons.	Number of herds.	Number of cows.	Yearly cost of feed per cow.	Pounds of milk yearly per cow.	Returns for $1 worth of feed.	Net profit per cow yearly.	Food cost of milk per 100 pounds.	Profitable herds.	Unprofitable herds.
Total of canvass	100	1,843	$35.60	4,536	$1.44	$15.68	$0.784	91	9
Cows:									
Dairy type	19	397	34.26	5,340	1.77	26.47	.641	19	0
Pure-bred herds	3	62	36.46	6,781	2.05	38.17	.537	3	0
Best grades	3	37	37.79	5,791	1.72	27.32	.652	3	0
Best mixed grades	3	60	43.88	5,950	1.58	25.35	.737	3	0
Feed									
Silage-fed herds	53	1,118	36.23	4,728	1.42	15.15	.766	51	2
Dry-fed herds	47	725	34.90	4,328	1.47	16.29	.806	40	7
Best silage-fed herds	5	86	39.88	6,701	1.88	35.19	.595	5	0
Best dry-fed herds	5	110	38.11	5,617	1.71	27.16	.678	5	0
Stables:									
Excellent	33	653	38.10	5,057	1.50	19.05	.753	33	0
Good	40	721	......	......	1.44	......	......	37	3
Fair	19	344	......	......	1.32	......	......	15	4
Poor	6	73	39.01	4,039	1.17	6.63	.965	4	2
Reading:									
Dairy literature	17	340	39.18	5,513	1.59	23.12	.71	17	0
Agricultural literature	50	920	......	......	1.43	......	......	46	4
Nothing	24	416	38.26	4,537	1.34	13.01	.845	19	5
Results:									
Best herds	10	152	32.13	5,715	1.99	32.01	.562	10	9
Unprofitable herds	9	133	39.65	3,051	.80	−7.71	1.30	0	9
Best combination of features	10	217	......	......	1.85	......	......	10	0

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[1] For explanation as to comparison, see footnote to canvass 2, page 14.

NOTES ON CANVASS NO. 21.

Of the best 10 herds, 7 are of good dairy type, 1 is dairy grades, and 2 are of mixed breeding; 7 are fed silage; 5 have excellent stables, 3 have good stables, 2 have fair stables; 3 owners read dairy papers, 5 read farm papers, and 2 read none.

Of the 9 unprofitable herds, none are of good dairy type, 3 are dairy grades, 6 are mixed or natives; 2 are fed silage; none have excellent stables, 3 have good stables, 4 have fair stables, and 2 have poor stables; no owner reads dairy papers, 2 read farm papers, and 5 read none.

Of the 16 herds which average a net profit per cow per year of $25 or more, 3 are pure bred, 9 dairy grades, and 4 mixed breeding; 8 have excellent stables, 6 have good stables; 4 owners read dairy literature, 9 read agricultural literature, and 11 feed silage.

The best combination of features is of herds of good dairy type using silage, having good or excellent stables, whose owners read dairy or farm papers. This group is a good illustration of the profitableness of good dairy equipment and practice.

COMPARISON WITH EARLIER CANVASS.

In 1887 the original cow census was taken in this town by C. W. Jennings, in which the total cow population of the town was included. There were 367 herds, kept at an average cost per cow per year of $36.26, and returning their owners an average of $31.74, showing a net loss of $4.62, and this with the reckoning of returns from cheese, butter, calves, skins, cream, milk, and skim milk; whereas in the canvass of 1906 the 100 representative herds show an average cost of keeping of $35.60 and returns from creamery checks of $51.28, making an average profit of $15.68 per cow yearly.

In 1887, of the 367 herds, 48 produced for their owners less than $25 total receipts per cow yearly, and only 3 produced more than $55. In 1906, of the 100 herds reported, only 1 produced less than $25 return and 31 exceeded $55, per cow, yearly.

CANVASS NO. 22.

Conducted in Iowa, 1906. Three counties in northeastern part of State. Patrons of eight creameries. Frank Kinsley, canvasser. 100 herds, 1,062 cows.

[Average price of butter fat, 22.7 cents per pound.]

Comparisons.	Number of herds.	Number of cows.	Yearly cost of feed per cow.	Pounds of butter fat yearly per cow.	Returns for $1 worth of feed.	Net profit per cow yearly.	Food cost of butter fat per pound.	Profitable herds.	Unprofitable herds.
Total of canvass	100	1,062	$28.23	154.0	$1.24	$6.78	$0.183	75	25
Cows:									
Dairy type	17	172	28.33	211.1	1.74	20.91	.134	16	1
Dual purpose	83	890	27.09	143.0	1.19	5.16	.197	59	24
Difference in favor of dairy-bred cows	......	......	−1.24	68.1	.55	15.75	.063	....	....
Feed: Silage fed	4	50	29.44	239.0	1.85	25.15	.123	4	0
Stables:									
Excellent	22	263	29.82	170.0	1.58	9.05	.175	19	3
Good	44	474			1.15			31	13
Fair	27	267	......	......	1.23	......	......	21	6
Poor	7	58	29.77	143.0	1.09	2.68	.208	4	3
Reading:									
Owners read dairy literature	50	559	28.02	178.5	1.48	13.45	.157	45	5
Owners do not read	46	463	27.70	121.9	1.01	.27	.227	26	20
Difference in favor of owners who read	......	......	− .32	56.6	.47	13.18	.07	....	....
Results:									
Best herds	25	273	28.17	209.7	1.74	20.83	.127	25	0
Unprofitable herds	25	257	28.92	100.0	.78	− 6.33	.29	0	25
Difference in favor of best herds	......	......	.75	109.7	.96	27.16	.163	....	....
Best single herd	1	14	29.00	322.0	2.48	42.92	.09	1	0
Poorest single herd	1	6	28.00	63.0	.43	−16.03	.44	0	1
Difference in favor of best herd	......	......	−1.00	259.0	2.05	58.95	.35	....	....

NOTES ON CANVASS NO. 22.

Stables excellent and good are averaged together in this table. The combined average return for one dollar's worth of feed is $1.30.

Of the 83 herds (890 cows) of the dual-purpose type, 30 per cent do not pay for their feed. Of the 17 herds (172 cows) of the dairy type, only 6 per cent do not pay for their feed.

The 172 dairy-bred cows produce on the average $15.75 more net profit than the 890 dual-purpose cows, return 55 cents more for each dollar spent in feed, and reduce the food cost of butter fat by 6.3 cents per pound, though consuming $1.24 more feed per cow.

The best single herd is of 14 Jerseys registered, line bred for 12 years, fresh in the fall, fed silage, with an excellent stable, and a reading owner.

The poorest single herd is of 6 Shorthorn grades, fresh in the fall, fed no silage, with a good stable, but with no reading by the owner.

The silage-fed cows consume $1.21 more feed, make $18.37 more net profit, return 61 cents more for each dollar spent on feed, and reduce the food cost of butter fat by 6 cents per pound, as compared with the average of the whole group, notwithstanding that one of the four herds does not pay for the feed consumed.

Fifty herds (559 cows), practically one-half of the whole group, whose owners read dairy papers, produce $318.19 more net profit than the whole group, return 24 cents more for one dollar invested in feed, and reduce the cost of butter fat 2.6 cents per pound. Of these herds only 5 do not pay for the feed consumed. (The statement that these 50 herds make more profit than the whole canvass of 100 herds, is based on the fact that the remaining 50 herds make an average loss. Of the losing 50, 46 owners do not read, while 4 are not reported as to reading.)

The 46 herds whose owners are reported as not reading dairy papers yield a total net profit of $125. They yield an average of 121.9 pounds of butter fat per cow, return $1.01 for each dollar invested in feed, and produce butter fat at a food cost of 22.7 cents per pound; 20 herds of this group do not pay for the feed consumed.

The ratio of profitable to unprofitable herds, which indicates the probability of success, is nearly seven times (6.9) as great among the readers as it is among those who do not read.[1]

In one herd where all the cows were tested and records kept during the year 1905, 45 per cent of the cows were found to be unprofitable and were sold during the following year. The remaining 55 per cent, with better feed and care, produced more butter fat, more gross cash returns, and more than double the returns for each dollar invested in feed; and produced butter fat at less than half of the food cost of the previous year.

If the summaries of this canvass be applied to the whole State, with 1,600,000 cows, we might say that, if all the cows were of dairy type, the net gains to the State would be 88,000,000 pounds of butter fat, valued at $20,000,000. If all the cows were fed silage, the gain would be 132,000,000 pounds of fat, or $28,000,000. If all the dairymen were students of dairy literature, the gain would be 39,000,000 pounds of fat, or $10,000,000. If the weeding-out process were applied to all the herds, as in the one case specified above, the gain would be $11,000,000 for the increased fat production and $19,000,000 by the saving in feed now given to robber cows which should be sent to the block.

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[1] For explanation as to comparison of ratios, see footnote to canvass 2, page 14.

CANVASS NO. 23.

Conducted in New Hampshire, 1906, among creamery patrons. H. H. Lyon, canvasser. 100 herds, 853 cows.

[Average price of butter fat, 23 cents.]

Comparisons.	Number of herds.	Number of cows.	Yearly cost of feed per cow.	Pounds of butter fat yearly per cow.	Returns for $1 worth of feed.	Net profit per cow yearly.	Food cost of butter fat per pound.	Profitable herds.	Unprofitable herds.
Total of canvass	100	853	$35.67	144.4	$0.93	—$2.50	$0.247	41	59
Cows:									
Dairy type	65	566	36.04	155.2	.99	— .20	.238	35	30
Not dairy type	35	287	35.00	121.6	.76	— 8.41	.287	6	29
Difference in favor of dairy type	......	......	— 1.04	33.6	.23	8.21	.049	....	....
Feed: Silage fed	18	196	34.67	158.7	1.006	0.20	.22	11	7
Stables:									
Good	41	349	37.40	175.1	1.10	3.74	.214	31	10
Fair	37	315	......	......	.87	......	......	8	29
Poor	18	153	34.44	93.9	.60	—13.78	.367	0	18
Reading:									
Dairy literature	20	170	36.95	188.7	1.19	7.02	.196	19	1
Agricultural literature	57	486	......	......	.90	......	......	19	38
Nothing	22	187	34.59	130.3	.73	— 9.34	.265	1	21
Results:									
Best herds	10	118	38.30	213.3	1.31	12.11	.179	10	0
Poorest herds	10	99	34.00	79.2	.51	—16.46	.43	0	10
Largest gain from single herd	1	7	25.02	249.2	1.87	21.80	.101	1	0
Largest loss from single herd	1	8	36.00	78.2	.48	—18.88	.46	0	1

NOTES ON CANVASS NO. 23.

The largest gain from a single herd in this canvass is from one consisting of Jersey grades (no pure-bred herd in this canvass), fresh in the fall, with good stable; owner reads dairy literature, and feeds a well balanced ration.

The largest average loss from a single herd is found in a herd of Hereford grades, fresh in the spring and fall, fed a fair ration and kept in a fair stable, the owner reading agricultural papers.

Of the 10 best herds, 3 are fed silage, 9 are grades of dairy breeds, 9 have good stables, 7 owners read dairy literature, 3 read agricultural literature. Every herd in this group makes an annual profit per cow of $9.41 or more (this is the average per cow of the lowest herd).

Of the poorest 10 herds, only 1 is fed silage, only 3 are grades of dairy breeds, 1 has a good stable, 2 have fair stables, and 7 have poor stables; none of the owners read dairy literature, 6 read agricultural literature, 4 read nothing. The best herd in this group loses an average of $15.55 per cow per year, the other herds losing still more.

Of the 20 readers of dairy papers, all but 4 have dairy bred herds, all but 3 have good stables, 3 have fair stables, 8 have silos, 12 feed good rations and 2 fair.

The average cost of keeping the profitable cows is $37. The average cost of keeping the losing cows is $34.82. The highest cost of feeding is $44; the lowest cost of feeding is $31.

Of the herds that make a profit, 41 in number, 23 are fed well-balanced rations, 11 are fed silage, 15 are fed rations low in protein. Net profit on cows fed well-balanced rations, $7.31; on those fed low protein, $5.08.

Of the 59 herds that make a loss, 12 are fed a well-balanced ration (loss $5.55), 7 are fed silage (loss $7.18), and 49 are fed a ration low in protein (loss $8.87).

On farms where profit is made, silos are nearly three times as frequent, feeds rich in protein are three times as frequent, readers of agricultural papers are three times as frequent, as on farms where loss ensues. A man who reads good dairy literature appears to have 19 chances of success to one of failure; while the man who reads nothing has one chance of success to 21 of failure. Improved blood gives five times the chance of success that the common mixed herd possesses.[1]

CANVASS NO. 24.

Conducted in Massachusetts, 1907. Five creameries in central and western Massachusetts, representing the cream-gathering plan. H. H. Lyon, canvasser. 50 herds, 473 cows.

[Average price of butter fat, 26.8 cents.]

Comparisons.	Number of herds.	Number of cows.	Yearly cost of feed per cow.	Pounds of butter fat yearly per cow.	Returns for $1 worth of feed.	Net profit per cow yearly.	Food cost of butter-fat per pound.	Profitable herds.	Unprofitable herds.
Total of canvass	50	473	$35.51	139.7	$1.02	$0.74	$0.254	19	31
Cows:									
Dairy bred	15	135	36.34	170.2	1.14	5.17	.214	9	6
Mixed breeds	35	338	35.14	126.6	.97	−1.14	.277	10	25
Stables:									
Good	15	147	37.80	172.4	1.16	6.05	.219	11	4
Fair	26	241	....	....	.96	....	....	7	19
Poor	9	85	33.89	117.9	.89	−3.73	.287	1	8
Reading:									
Dairy literature	19	154	36.53	165.8	1.12	4.38	.22	11	8
Agricultural literature	21	235	....	....	.96	....	....	7	14
Nothing	10	84	33.60	112.4	.87	−4.37	.299	1	9
Results:									
Best herds	5	47	40.20	228.0	1.43	17.50	.185	5	0
Poorest herds	5	47	34.00	91.5	.75	−8.54	.371	0	5

NOTES ON CANVASS NO. 24.

All the best five herds are of dairy type, except one. All owners are readers; all but one have good stables. Range of profit per cow annually $8.52 to $25.75.

Of the 5 poorest herds, 2 are of dairy type, and 3 of mixed breeding. One owner reads dairy literature; 2 read agricultural literature; 2 read nothing; 1 has a good stable; 2 have fair stables; and 2 poor stables. Range in amount of net loss by these herds, $7.40 to $11.10 per cow per year.

The use of silage in this canvass is inconclusive, only 4 herds being reported as using silage.

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[1] Compare the ratios 35 : 30 and 6 : 29. See footnote to canvass 2, p. 14.

CANVASS NO. 25.

Conducted in three counties in northwestern Illinois, 1907. Frank Kinsley, canvasser. 100 herds, 1,400 cows.

[Patrons of eight creameries. About three-quarters of these farmers are tenant farmers, the usual plan being for the owner to furnish one-half the stock and seed, in addition to the real estate, and receive one-half the proceeds. Acreage of farms, 160 to 320. Land values, $60 to $150 an acre. Average price of butter fat per pound, 27.5 cents.]

Comparisons.	Number of herds.	Number of cows.	Yearly cost of feed per cow.	Pounds of butter fat yearly per cow.	Returns for $1 worth of feed.	Net profit per cow yearly.	Food cost of butter fat per pound.	Profitable herds.	Unprofitable herds.
Total of canvass	100	1,400	$32.76	145.1	$1.21	$7.03	$0.245	70	30
Cows:									
Dairy type	27	385	31.73	178.0	1.54	17.23	.185	27	0
Dual purpose	73	1,015	33.27	133.0	1.10	3.50	.27	43	30
Difference in favor of dairy-type herds			1.54	45.0	.44	13.73	.085		
Feed: Silage fed	7	184	29.00	197.0	1.87	25.18	.161	7	0
Stables:									
Very good	29	406	31.10	153.0	1.47	10.95	.208	26	3
Good	26	364			1.22			20	6
Fair	43	602			1.07			23	20
Poor	2	28	32.05	119.0	1.02	.64	.269	1	1
Reading:									
Dairy papers	27	416	32.48	180.0	1.53	17.21	.19	27	0
Farm papers	41	552	32.97	150.0	1.25	8.27	.235	30	11
Nothing	32	432	32.31	110.0	.94	−1.94	.30	13	19
Difference per cow in favor of readers of dairy papers over nonreaders			−0.17	70.0	.59	19.15	.11		
Results:									
Best herds, one-quarter of canvass	25	340	33.07	204.0	1.68	22.68	.16	25	0
Poorest herds, one-quarter of canvass	25	360	33.11	97.0	.80	−6.45	.342	0	25
Difference in favor of best herds			.04	107.0	.88	29.13	.182		
Most economical producers	10	363	32.48	237.7	2.01	32.93	.138	10	0
Least economical producers	10	.139	31.10	84.0	.74	−7.98	.37	0	10
Difference in favor of the most economical producers			−1.38	154.0	1.27	40.91	.232		

NOTES ON CANVASS NO. 25.

Stables very good and good are averaged together in the table. The combined average return for one dollar's worth of feed is $1.35.

The 385 dairy-bred cows produced $3,081.05 more net profit than the 1,015 dual-purpose cows. They return 44 cents more for each dollar in feed and produce butter fat at a cost of 8.5 cents per pound less.

Of the 27 dairy-bred herds, 12 have very good stables, 7 have good stables, 8 have fair stables. Only 1 of these owners does not read.

The 7 herds using silage are fed at a cost of $3.76 less and produce a profit $18.15 more, return for each dollar's worth of feed 66 cents more, and produce butter fat at a cost per pound 8.4 cents less than the average of the whole canvass.

The 10 herds producing with greatest economy produce butter fat at a cost of from 9.5 to 16 cents per pound, and return for every dollar spent in feed from $1.73 to $2.87. Four of these are fed silage; the owners all read; 7 have very good stables; 1 has a good stable; 2 have fair stables; 7 herds are dairy bred; 3 dual purpose.

Of the 10 least economical herds, none are of dairy type; only 3 owners read; 2 have very good stables; 2 have good stables; 6 have fair stables.

Of the 10 herds producing with greatest economy, 7 owners read dairy papers and 3 read farm papers. Of the 10 producing with least economy, 3 owners read farm papers and 7 read none.

Of the 27 readers of dairy papers, 14 have herds of dairy type, 13 have dual purpose; 6 feed silage; 13 have very good stables; 5 good, and 9 fair. All these herds are profitable.

Of the 41 herds whose owners read farm papers, only 30 are profitable and 11 are unprofitable; 1 uses silage; 12 herds are of dairy type and 29 dual purpose; 11 have very good stables, 16 good stables, and 14 fair stables.

Of the 32 owners who do not read, only 1 has a herd of dairy type; none use silage; 13 of these herds are profitable and 19 are unprofitable; 5 have very good stables, 5 good stables, 20 fair stables, and 2 poor stables.

All the owners of very good stables except 5 are readers; 20 owners of good stables are readers; 23 owners of fair stables are readers; and both owners of poor stables answered no in regard to reading.

CANVASS NO. 26.

Conducted in vicinity of Bainbridge, N. Y., 1908. Creamery patrons. Six years later than canvass No. 8 of patrons of the same creamery. H. H. Lyon, canvasser. 100 herds, 1,724 cows.

[Average price of milk, $1.42; hay, $12 a ton; grain, $30 a ton; silage, $3 a ton.]

Comparisons.	Number of herds.	Number of cows.	Yearly cost of feed per cow.	Pounds of milk yearly per cow.	Returns for $1 worth of feed.	Net profit per cow yearly.	Food cost of milk per 100 pounds.	Profitable herds.	Unprofitable herds.
Total of canvass	100	1,724	$46.78	4,455	$1.36	$17.01	$1.05	83	17
Cows:									
Dairy type	49	916	49.08	5,334	1.60	29.58	.92	49	0
Mixed breeds	51	809	44.64	3,600	1.11	4.91	1.24	34	17
Fresh in fall	5	43	51.40	5,506	1.66	33.90	.983	5	0
Fresh in spring	32	443	43.30	3,577	1.10	4.38	1.20	20	12
Feed: Silage fed	18	469	48.00	5,123	1.58	27.84	.937	17	1
Stables:									
Very good	10	184	49.40	5,082	1.49	24.05	.961	9	1
Good	55	1,025	48.23	4,911	1.50	24.15	982	53	2
Fair	30	468	44.17	3,670	1.13	5.58	1.203	20	10
Poor	5	58	41.40	2,805	.92	−3.46	1.44	1	4
Reading:									
Dairy literature	13	287	49.08	5,380	1.62	30.39	.912	13	0
Nothing	23	377	43.70	3,261	1.02	.87	1.34	11	12
Results:									
Best herds	10	162	52.45	6,582	1.88	46.45	.796	10	0
Poorest herds	10	173	43.60	2,662	.83	−7.19	1.64	0	10

NOTES ON CANVASS NO. 26.

Of the 10 best herds, all are of dairy type, 3 are fresh in the fall, 1 in the spring; 3 have very good stables, 7 have good stables. Three owners read dairy literature, 7 read farm papers; 4 herds use silage.

Of the 10 poorest herds, none are of dairy type; 6 are fresh in the spring, 4 in the spring and fall; 1 has a very good stable, 2 have good stables, 5 have fair stables, and 2 have poor stables; 1 owner reads a farm paper, 9 read nothing; 1 herd uses silage.

Of the dairy-type herds, 4 are fresh in the fall and 3 in the spring, 39 in spring and fall, 3 not reported; 5 have very good stables, 41 have good stables, 3 have fair stables; 11 owners read dairy literature, 36 read farm papers, 1 reads nothing, and 1 is not reported; 16 herds use silage.

Of the mixed, native, and common herds, 29 are fresh in the spring, 1 is fresh in the fall, 20 fresh in spring and fall, and 1 not reported; 5 have very good stables, 14 have good stables, 27 have fair stables, and 5 have poor stables; 2 owners read dairy literature, 27 read farm papers, and 22 read nothing; 2 herds use silage.

Of the 5 herds fresh in the fall, 4 are of dairy type, 1 uses silage; 1 has a very good stable, 3 have good stables, and 1 has a fair stable; 2 owners read dairy literature and 3 read farm papers.

Of the 32 herds fresh in the spring, only 3 are of dairy type, none use silage; 2 have very good stables, 6 have good stables, 21 have fair stables, and 3 have poor stables; 1 owner reads dairy literature, 17 read farm papers, and 14 read nothing.

Of the 18 herds using silage, only 1 is unprofitable, and that is not of dairy type, and the owner is not a reader; 16 herds are of dairy type; 1 is fresh in the fall, 17 are fresh in spring and fall; 2 have very good stables, 16 have good stables; 7 owners read dairy literature, 10 read farm papers, and 1 reads nothing.

Of the 10 herds having very good stables, 5 are of dairy type; the 1 unprofitable herd is of scrub type, and the owner does not read; 2 herds use silage; 1 is fresh in the fall, 2 are fresh in the spring, and 7 are fresh in spring and fall; 2 owners read dairy literature, 6 read farm papers, and 2 read nothing.

Of the 5 herds occupying poor stables, all are of scrub type, none use silage; 3 are fresh in the spring, 1 fresh in the spring and fall, and 1 not reported; 2 owners read farm papers and 3 read nothing.

Of the 13 owners who read dairy literature, 11 have dairy type herds, 7 use silage; 2 have very good stables, 9 have good stables, 2 have fair stables; 2 herds are fresh in the fall, 1 in the spring, and 10 in spring and fall.

Of the 23 owners who do not read, only 1 has a dairy-type herd and only 1 feeds silage; 2 have very good stables, 4 have good stables, 14 have fair stables, and 3 have poor stables; 13 herds are fresh in the spring and 10 in spring and fall.

GENERAL SUMMARY OF THE CANVASSES.

The following table shows a comparison of the 26 canvasses, taking the totals and averages of each canvass separately, together with totals and general averages for the whole series of canvasses. The features particularly discussed in each canvass are indicated by initial letters in the last column of the table, as follows:

D. Type of cows (dairy type or lacking dairy type).
F. Freshening of cows in different seasons.
H. Raising heifers to build up herd.
E. Use of silage (ensilage).
C. Use of soiling crops.
P. Use of purchased or home-grown protein.
A. Use of alfalfa.
S. Character of stabling.
R. Reading dairy literature, or general agricultural papers, or neglect of reading.
B. Patrons of Borden's condensing factory compared with patrons of a cooperative creamery.

SUMMARY A.

General summary of canvasses.

Serial No.	Location, and date of canvass.	Number of herds.	Number of cows.	Yearly cost of feed per cow.	Pounds of milk yearly per cow.	Pounds of butter yearly per cow.	Pounds of butter fat yearly per cow.	Price of milk per 100 pounds.	Price of butter per pound.	Price of butter fat per pound.	Returns for $1 worth of feed.	Net profit per cow yearly.	Food cost of milk per 100 pounds.	Food cost of butter per pound.	Food cost of butter fat per pound.	Profitable herds.	Unprofitable herds.	Features discussed (see note).
1	Wisconsin, 1899, Jefferson County.	100	1,804	$29.33	4,990	233	....	$0.886	$0.188	....	$1.50	$14.62	$0.588	$0.126	....	98	2	ED SP.
2	Iowa, 1899, five counties.	100	882	26.05	3,600	159	....	.807	.194	....	1.16	4.16	.702	.169	....	62	38	EDR.
3	Ohio, 1899-1900, five counties.	100	994	26.58	4,048	214	....	1.050	.198	....	1.60	15.94	.656	.124	....	97	3	ED S.
4	New York, 1900, Delaware and Otsego Counties.	100	1,704	31.99	3,623	188	....	.930	.18	....	1.05	1.60	.883	.17	....	53	47	EDRSC.
5	Pennsylvania, 1901, Susquehanna County.	60	663	33.04	3,879	....	....	1.056	....	....	1.26	8.03	.852	....	....	39	11	EDRS.
6	Wisconsin, 1901, Dunn County.	52	647	26.96	4,796	222	....	.826	.178	....	1.47	12.03	.562	.122	....	51	1	D.
7	New York, 1901-2, Onondaga County.	80	948	30.07	3,981	184	....	.893	.193	....	1.19	5.79	.755	.163	....	54	26	DRSA.
8	New York, 1901-2, Bainbridge creamery.	100	1,553	38.10	3,908	....	....	.995	....	....	1.02	.89	.975	....	....	58	42	EDRS.
9	Wisconsin, 1901-2, creamery and cheese factory.	60	809	29.88	4,204	185	....	.852	.193	....	1.20	5.94	.71	.161	....	46	14	ED.
10	New York, 1901-2, Onondaga Milk Association.	45	1,022	43.71	5,296	....	....	1.066	....	....	1.30	13.05	.825	....	....	34	11	EDRSA.
11	Indiana, 1902-3, Marshall County.	50	282	24.96	3,730	....	166	.850	....	$0.194	1.26	6.57	.668	....	$0.15	39	11	EDR.
12	Ohio, 1903, Geauga County, cheese factory.	100	1,027	28.20	4,547	....	....	.889	....	....	1.46	13.02	.62	....	....	92	8	EDRSH.
13	Ohio, 1904, Lorain and Medina Counties.	87	635	26.98	3,858	195	....	.773	.151	....	1.10	2.80	.70	.14	....	55	32	EDRSH.
14	Pennsylvania, 1904, Wayne and Franklin Counties.	99	858	29.44	3,250	153	....	.840	.18	....	.94	−1.85	.90	.192	....	39	60	EDRS.
15	Connecticut, 1904, Andover creamery.	50	445	37.02	....	....	138.2	....	....	.27	1.004	.13	....	....	.268	24	26	EDRS.
16	Vermont, 1904, four counties, central north.	100	1,914	36.57	....	....	150.5	....	....	.222	.91	−3.20	....	....	.242	32	68	EDRS.

17	Minnesota, 1904, creamery.	100	1,092	24.90	....	....	142.4	....	....	.211	1.21	5.15	....	....	.175	66	34	EDRS.
18	Wisconsin, 1905, Waukesha County.	40	556	30.00	....	202	....	....	.204	....	1.38	11.29	....	.148	....	38	2	DR F.
19	New York, 1904-5, Delaware County.	100	2,408	38.69	4,083	....	186.4	1.334	....	.288	1.44	17.25	.947	....	.205	97	3	EDRSB.
20	Michigan, 1905, Butler and Jackson Counties.	100	849	32.12	4,093	....	177.4	1.010	....	23	1.25	8.14	.784	....	.181	78	22	EDRS.
21	New York, 1906, Ellisburg.	100	1,843	35.60	4,536	....	....	1.130	....	....	1.44	15.68	.784	....	....	91	9	EDRS.
22	Iowa, 1906, three counties, northeast.	100	1,062	28.23	....	....	154	....	....	.227	1.24	6.78	....	....	.183	75	25	EDRS.
23	New Hampshire, 1906, creamery.	100	853	35.67	....	....	144.4	....	....	.233	.93	−2.50	....	....	.247	41	59	EDRS.
24	Massachusetts, 1907, central and western.	50	473	35.51	....	....	139.7	....	....	.268	1.02	.74	....	....	.254	19	31	DRS.
25	Illinois, 1907, three counties, northwest.	100	1,400	32.76	....	....	145.1	....	....	.275	1.21	7.03	....	....	.245	70	30	EDRS.
26	New York, 1908, Bainbridge, second time.	100	1,724	46.78	4,455	....	....	1.420	....	....	1.36	17.01	1.05	....	....	83	17	EDRSF.
	Total..............	2,163	28,447	....	....	....	....	....	....	....	....	....	....	....	....	1,531	632	
	Average..............	....	....	33.43	4,213	196	158.4	1.036	.186	.249	1.24	8.11	.802	.148	.213	....	....	

SUMMARIES BY SPECIAL FEATURES.

The next series of nine tables presents summaries of the canvasses by special features; and these are followed by a general summary of the whole series of canvasses by features.

The list of summaries is as follows:

A. General summary of canvasses.
B. Herds of good dairy type.
C. Herds lacking dairy type.
D. Herds fed silage.
E. Good or excellent stables.
F. Poor stables.
G. Owners who read dairy literature.
H. Owners who do not read dairy literature.
I. Most profitable herds.
J. Least profitable herds.
K. General summary by features.

SUMMARY B.

Herds of good dairy type.

Serial No.	Location and date of canvass.	Number of herds.	Number of cows.	Yearly cost of feed per cow.	Pounds of milk yearly per cow.	Pounds of butter yearly per cow.	Pounds of butter fat yearly per cow.	Returns per $1 worth of feed.	Net profit per cow yearly.	Food cost of milk per 100 pounds.	Food cost of butter per pound.	Food cost of butter fat per pound.	Profitable herds.	Unprofitable herds.
1	Wisconsin, 1899, Jefferson County	76	1,306	$29.22	5,180	244		$1.60	$17.53	$0.564	$0.119		76	0
2	Iowa, 1899, five counties	17	160	26.18	5,030	248		1.78	20.43	.52	.105		17	0
3	Ohio, 1899-1900, five counties, east	39	418	27.05	4,548	249		1.88	23.80	.594	.108		39	0
4	New York, 1900, Delaware and Otsego Counties	40	712	32.27		229		1.28	8.93		.141		37	3
5	Pennsylvania, 1901, Susquehanna County	15	235	33.08	5,007			1.63	20.85	.70			15	0
6	Wisconsin, 1901, Dunn County	14	193	26.71	5,356	236		1.68	18.05	.491	.113		14	0
7	New York, 1901-2, Onondaga County	20	235	28.00	5,044	245		1.67	18.76	.553	.114		20	0
8	New York, 1901-2, Bainbridge creamery	27	428	38.98	4,629			1.20	7.79	.842			25	2
9	Wisconsin, 1901-2, creamery and cheese factory	13	197	31.70	5,059	235		1.48	15.30	.626	.135		13	0
10	New York, 1901-2, Onondaga Milk Association	8	166	45.25	6,923			1.67	30.32	.653			7	1
11	Indiana, 1902-3, Marshall County	16	94	25.18	4,540		208.5	1.61	15.30	.554		$0.12	15	1
12	Ohio, 1903, Geauga County, cheese factory	50	572	28.86	5,289			1.69	19.91	.545			49	1
13	Ohio, 1904, Lorain and Medina Counties	29	244	27.29	4,374	235		1.30	8.10	.624	.12		23	6
14	Pennsylvania, 1904, Wayne and Franklin Counties	10	78	30.86	4,508	214		1.32	9.83	.68	.144		10	0
15	Connecticut, 1904, Andover creamery	7	88	38.25			161.9	1.18	6.91			.236	5	2
16	Vermont, 1904, central and northern	12	354	37.21			207.5	1.32	11.90			.179	11	1
17	Minnesota, 1904, creamery	14	155	28.02			219.8	1.65	18.13			.128	14	0
18	Wisconsin, 1905, Waukesha County	17	203	30.16		244		1.69	20.81		.124		17	0
19	New York, 1904-5, Delaware County	26	826	39.26			199.3	1.53	20.81			.197	25	1
20	Michigan, 1905, Butler and Jackson Counties	10	130	24.77	4,430		204.0	1.96	23.82	.559		.121	10	0
21	New York, 1906, Ellisburg	19	397	34.26	5,340			1.77	26.47	.641			19	0
22	Iowa, 1906, three counties, northeast	17	172	28.33			211.1	1.74	20.91			.134	16	1
23	New Hampshire, 1906, creamery	65	566	36.04			155.2	.99	− 0.20			.238	35	30
24	Massachusetts, 1907, central and western	15	135	36.34			170.2	1.14	5.17			.214	9	6
25	Illinois, 1907, three counties, northwest	27	385	31.73			178.0	1.54	17.23			.185	27	0
26	New York, 1908, Bainbridge, second time	49	916	49.03	5,334			1.60	29.58	.92			49	0
	Total	652	9,365										597	55
	Average			33.95	5,104	240	189.0	1.51	17.38	.656	.122	.185		

SUMMARY C.

Herds lacking dairy type.

Serial No.	Location and date of canvass.	Number of herds.	Number of cows.	Yearly cost of feed per cow.	Pounds of milk yearly per cow.	Pounds of butter yearly per cow.	Pounds of butter fat yearly per cow.	Returns for $1 worth of feed.	Net profit per cow yearly.	Food cost of milk per 100 pounds.	Food cost of butter per pound.	Food cost of butter fat per pound.	Profitable herds.	Unprofitable herds.
1	Wisconsin, 1899, Jefferson County	24	498	$29.67	4,390	196	......	$1.22	$6.67	$0.675	$0.151	......	22	2
2	Iowa, 1899, five counties	83	722	25.46	3,150	134	......	1.02	.54	.82	.19	......	45	38
3	Ohio, 1899-1900, five counties, east	20	170	27.60	3,510	174	......	1.31	8.56	.786	.158	......	17	3
4	New York, 1900, Delaware and Otsego Counties	50	801	31.54	......	158	......	.89	− 3.43	......	.20	......	10	40
5	Pennsylvania, 1901, Susquehanna County	21	265	32.00	3,296	......	......	1.05	1.70	.97	......	......	13	8
6	Wisconsin, 1901, Dunn County	30	344	27.06	4,382	197	......	1.34	9.27	.617	.137	......	29	1
7	New York, 1901-2, Onondaga County	23	254	31.00	3,084	143	......	.87	− 3.87	1.005	.216	......	9	14
8	New York, 1901-2, Bainbridge creamery	12	185	36.43	3,116	......	......	.85	− 5.27	1.105	......	......	2	10
9	Wisconsin, 1901-2, creamery and cheese factory	16	195	29.25	3,731	160	......	1.05	1.60	.784	.183	......	8	8
10	New York, 1901-2, Onondaga Milk Association	5	139	44.60	3,415	......	......	.84	− 7.05	1.30	......	......	1	4
11	Indiana, 1902-3, Marshall County	19	124	25.90	3,113	......	139.0	1.09	1.87	.832	......	$0.186	10	9
12	Ohio, 1903, Geauga County, cheese factory	29	233	26.51	3,361	......	......	1.12	3.18	.785	......	......	22	7
13	Ohio, 1904, Lorain and Medina Counties	34	217	26.88	3,389	165	......	.92	− 2.10	.792	.162	......	14	20
14	Pennsylvania, 1904, Wayne and Franklin Counties	8	59	31.96	2,494	114	......	.62	−12.08	1.28	.279	......	0	8
15	Connecticut, 1904, Andover creamery [1]	......	......	......	......	......	......	......	......	......	......	......	......	......
16	Vermont, 1904, central and northern [1]	......	......	......	......	......	......	......	......	......	......	......	......	......
17	Minnesota, 1904, creamery [1]	......	......	......	......	......	......	......	......	......	......	......	......	......
18	Wisconsin, 1906, Waukesha County	9	150	29.89	......	159	......	1.07	2.09	......	.188	......	7	2
19	New York, 1904-5, Delaware County	15	340	34.66	......	......	162.4	1.30	10.50	......	......	.213	13	2
20	Michigan, 1905, Butler and Jackson Counties	10	69	38.57	3,542	......	158.5	1.01	.39	1.088	......	.243	5	5
21	New York, 1906, Ellisburg [1]	......	......	......	......	......	......	......	......	......	......	......	......	......
22	Iowa, 1906, three counties, northeast	83	890	27.09	......	......	143.0	1.19	5.16	......	......	.197	59	24
23	New Hampshire, 1906, creamery	35	287	35.00	......	......	121.6	.76	− 8.41	......	......	.287	6	29
24	Massachusetts, 1907, central and western	35	338	35.14	......	......	126.6	.97	− 1.14	......	......	.277	10	25
25	Illinois, 1907, three counties, northwest	73	1,015	33.27	......	......	133.0	1.10	3.50	......	......	.27	43	30
26	New York, 1908, Bainbridge, second time	51	809	44.64	3,600	......	......	1.11	4.91	1.24	......	......	34	17
	Total	685	8,104	......	......	......	......	......	......	......	......	......	379	306
	Average	......	......	32.01	3,550	162	138.2	1.06	2.03	.908	.178	.23	......	......

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[1] Herds lacking dairy type not indicated in this canvass.

SUMMARY D.

Herds fed silage.

Serial No.	Location and date of canvass.	Number of herds.	Number of cows.	Yearly cost of feed per cow.	Pounds of milk yearly per cow.	Pounds of butter yearly per cow.	Pounds of butter fat yearly per cow.	Returns for $1 worth of feed.	Net profit per cow yearly.	Food cost of milk per 100 pounds.	Food cost of butter per pound.	Food cost of butter fat per pound.	Profitable herds.	Unprofitable herds.
1	Wisconsin, 1899, Jefferson County	18	508	$31.06	5,623	254		$1.57	$17.11	$0.552	$0.122		18	0
2	Iowa, 1899, five counties	3	70	29.00	5,767	302		1.98	28.32	.503	.096		3	0
3	Ohio, 1899–1900, five eastern counties	40	506	25.82	4,278	230		1.75	19.35	.603	.112		39	1
4	New York, 1900, Delaware and Otsego Counties	26	566	31.77		192		1.10	3.22		.165		14	12
5	Pennsylvania, 1901, Susquehanna County	14	259	34.21	4,525			1.41	13.91	.756			12	2
6	Wisconsin, 1901, Dunn County[1]													
7	New York, 1901–2, Onondaga County[1]													
8	New York, 1901–2, Bainbridge creamery	25	548	38.68	4,139			1.06	2.32	.935			15	10
9	Wisconsin, 1901–2, creamery and cheese factory	6	111	31.50	5,928	260		1.68	21.42	.531	.121		6	0
10	New York, 1901–2, Onondaga Milk Association	14	389	42.43	4,968			1.26	10.96	.853			11	3
11	Indiana, 1902–3, Marshall County	5	45	23.57	4,823		211.3	1.71	16.74	.503		$0.115	5	0
12	Ohio, 1903, Geauga County, cheese factory	15	241	31.06	5,501			1.71	22.05	.564			15	0
13	Ohio, 1904, Lorain and Medina Counties	8	95	27.00	4,596	251		1.42	11.51	.587	.107		7	1
14	Pennsylvania, 1904, Wayne and Franklin Counties	2	27	30.79	4,338	204		1.36	11.08	.710	.150		2	0
15	Connecticut, 1904, Andover creamery	1	14	38.75			191.3	1.44	17.19			.203	1	0
16	Vermont, 1904, central and northern	19	642	36.05			160.9	1.04	1.55			.224	12	7
17	Minnesota, 1904, creamery	3	40	29.12			275.0	1.80	23.36			.106	3	0
18	Wisconsin, 1905, Waukesha County[1]													
19	New York, 1904–5, Delaware County	12	382	40.12	4,026		194.2	1.44	17.73	.996		.206	12	0
20	Michigan, 1905, Butler and Jackson Counties	18	229	27.79	4,398		192.2	1.66	18.28	.631		.145	17	1
21	New York, 1906, Ellisburg	53	1,118	36.23	4,728			1.42	15.15	.766			51	2
22	Iowa, 1906, three counties, northeast	4	50	29.44			239.0	1.85	25.15			.123	4	0
23	New Hampshire, 1906, creamery	18	196	34.67			158.7	1.00	.20			.220	11	7
24	Massachusetts, 1907, central and western[1]													
25	Illinois, 1907, three counties, northwest	7	184	29.00			197.0	1.87	25.18			.161	7	0
26	New York, 1908, Bainbridge, second time	18	469	48.00	5,123			1.58	27.84	.937			17	1
	Total	329	6,689										282	47
	Average			34.98	4,760	230	181.8	1.39	13.50	.747	.129	.189		

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[1] Use of silage not reported.

SUMMARY E.

Herds having good or excellent stables.[1]

Serial No.	Location and date of canvass.	Number of herds.	Number of cows.	Yearly cost of feed per cow.	Pounds of milk yearly per cow.	Pounds of butter yearly per cow.	Pounds of butter fat yearly per cow.	Returns for $1 worth of feed.	Net profit per cow yearly.	Food cost of milk per 100 pounds.	Food cost of butter per pound.	Food cost of butter fat per pound.	Profitable herds.	Unprofitable herds.
1	Wisconsin, 1899, Jefferson County	55	990	$29.37	5,192	247	......	$1.61	$17.92	$0.565	$0.115	......	55	0
2	Iowa, 1899, five counties [2]	......	......	......	......	......	......	......	......	......	......	......	......	......
3	Ohio, 1899-1900, five counties, east	50	535	26.92	4,447	237	......	1.78	21.00	.605	.114	......	50	0
4	New York, 1900, Delaware and Otsego Counties	33	561	33.27	4,248	229	......	1.23	7.65	.783	.146	......	28	5
5	Pennsylvania, 1901, Susquehanna County	13	173	34.62	5,041	......	......	1.56	19.39	.687	......	......	12	1
6	Wisconsin, 1901, Dunn County [2]	......	......	......	......	......	......	......	......	......	......	......	......	......
7	New York, 1901-2, Onondaga County	11	132	30.73	5,071	244	......	1.63	19.36	.606	.126	......	11	0
8	New York, 1901, Bainbridge creamery	43	666	38.98	4,256	......	......	1.10	4.05	.914	......	......	28	15
9	Wisconsin, 1901-2, creamery and cheese factory [2]	......	......	......	......	......	......	......	......	......	......	......	......	......
10	New York, 1901-2, Onondaga Milk Association	36	817	43.89	5,998	......	......	1.35	15.30	.732	......	......	27	9
11	Indiana, 1902-3, Marshall County [2]	......	......	......	......	......	......	......	......	......	......	......	......	......
12	Ohio, 1903, Geauga County, cheese factory	16	162	30.35	5,270	......	......	1.60	18.21	.576	......	......	16	0
13	Ohio, 1904, Lorain and Medina Counties	3	22	27.33	4,704	279	......	1.61	16.67	.581	.098	......	3	0
14	Pennsylvania, 1904, Wayne and Franklin Counties	2	16	30.64	3,825	181	......	1.12	3.68	.801	.169	......	2	0
15	Connecticut, 1904, Andover creamery	3	55	37.63	......	......	157.8	1.28	10.54	......	......	$0.238	3	0
16	Vermont, 1904, central and northern	6	215	36.91	......	......	177.2	1.38	14.03	......	......	.208	6	0
17	Minnesota, 1904, creamery	57	560	24.39	......	......	156.0	1.20	4.93	......	......	.163	41	16
18	Wisconsin, 1905, Waukesha County [2]	......	......	......	......	......	......	......	......	......	......	......	......	......
19	New York, 1904-5, Delaware County	53	1,403	40.12	4,160	......	206.1	1.50	20.06	.964	......	.195	53	0
20	Michigan, 1905, Butler and Jackson Counties	38	359	27.10	4,749	......	206.0	1.81	21.84	.571	......	.131	38	0
21	New York, 1906, Ellisburg	33	653	38.10	5,057	......	......	1.50	19.05	.753	......	......	33	0
22	Iowa, 1906, three counties, northeast	66	737	29.82	......	......	170.0	1.30	9.05	......	......	.175	50	16
23	New Hampshire, 1906, creamery	41	349	37.40	......	......	175.1	1.10	3.74	......	......	.214	31	10
24	Massachusetts, 1907, central and western	15	147	37.80	......	......	172.4	1.16	6.05	......	......	.219	11	4
25	Illionois, 1907, three counties, northwest	55	770	31.10	......	......	153.0	1.35	10.95	......	......	.203	46	9
26	New York, Bainbridge, second time	10	184	49.40	5,032	......	......	1.49	24.05	.981	......	......	9	1
	Total	639	9,506	......	......	......	......	......	......	......	......	......	553	86
	Average	......	......	34.53	4,793	240	180.0	1.41	14.12	.75	.124	.187	......	......

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[1] It will be observed that in the canvasses stables are variously classified. The summary includes the best class from each canvass, however named, and in some cases a combination of the two best classes.

[2] Stabling not reported.

SUMMARY F.

Herds having poor stables.

Serial No.	Location and date of canvass.	Number of herds.	Number of cows.	Yearly cost of feed per cow.	Pounds of milk yearly per cow.	Pounds of butter yearly per cow.	Pounds of butter fat yearly per cow.	Returns for $1 worth of feed.	Net profit per cow yearly.	Food cost of milk per 100 pounds.	Food cost of butter per pound.	Food cost of butter fat per pound.	Profitable herds.	Unprofitable herds.
1	Wisconsin, 1899, Jefferson County	12	220	$28.83	3,950	177		$1.14	$4.04	$0.73	$0.163		10	2
2	Iowa, 1899, five counties [1]													
3	Ohio, 1899-1900, five counties, east	15	117	26.47	3,274	168		1.29	7.68	.809	.157		13	2
4	New York, 1900, Delaware and Otsego Counties	17	293	30.94	2,841	144		.82	− 5.57	1.089	.215		1	16
5	Pennsylvania, 1901, Susquehanna County	15	199	32.87	3,073			.98	− .66	1.07			6	9
6	Wisconsin, 1901, Dunn County [1]													
7	New York, 1901-2, Onondaga County	33	396	30.53	3,488	162		1.10	3.05	.875	.188		16	17
8	New York, 1901-2, Bainbridge creamery	25	387	35.76	3,255			.87	− 4.50	1.099			8	17
9	Wisconsin, 1901-2, creamery and cheese factory [1]													
10	New York, 1901-2, Onondaga Milk Association	9	204	41.89	4,380			1.12	5.24	.956			7	2
11	Indiana, 1902-3, Marshall County [1]													
12	Ohio, 1903, Geauga County, cheese factory	33	334	26.81	3,954			1.35	9.38	.671			28	5
13	Ohio, 1904, Lorain and Medina Counties	40	291	25.91	3,488	178		1.08	1.99	.743	.145		25	15
14	Pennsylvania, 1904, Wayne and Franklin Counties	5	28	32.20	3,218	152		.80	− 6.44	1.001	.212		1	4
15	Connecticut, 1904, Andover creamery	6	46	36.50			111.8	.79	− 7.66			$0.326	0	6
16	Vermont, 1904, central and northern	15	214	36.53			123.2	.73	− 9.86			.297	0	15
17	Minnesota, 1904, creamery	15	156	23.40			114.2	1.01	.19			.205	8	7
18	Wisconsin, 1905, Waukesha County [1]													
19	New York, 1904-5, Delaware County	13	258	36.55	3,296		143.0	1.15	5.48	1.109		.255	10	3
20	Michigan, 1905, Butler and Jackson Counties	23	177	41.21	3,960		173.0	.97	− 1.24	1.04		.238	9	14
21	New York, 1906, Ellisburg	6	73	39.01	4,039			1.17	6.63	.965			4	2
22	Iowa, 1906, three counties, northeast	7	58	29.77			143.0	1.09	2.68			.208	4	3
23	New Hampshire, 1906, creamery	18	153	34.44			93.9	.60	−13.78			.367	0	18
24	Massachusetts, 1907, central and western	9	85	33.89			117.9	.89	− 3.73			.287	1	8
25	Illinois, 1907, three counties, northwest	2	28	32.05			119.0	1.02	.64			.269	1	1
26	New York, 1908, Bainbridge, second time	5	58	41.40	2,805			.92	− 3.46	1.44			1	4
	Total	323	3,775										153	170
	Average			32.53	3,514	164	130.0	1.01	.23	.927	.177	.266		

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[1] Stabling not reported.

SUMMARY G.

Herds whose owners read dairy literature.

Serial No	Location and date of canvass.	Number of herds.	Number of cows.	Yearly cost of feed per cow.	Pounds of milk yearly per cow.	Pounds of butter yearly per cow.	Pounds of butter fat yearly per cow.	Returns for $1 worth of feed.	Net profit per cow yearly.	Food cost of milk per 100 pounds.	Food cost of butter per pound.	Food cost of butter fat per pound.	Profitable herds.	Unprofitable herds.
1	Wisconsin, 1899, Jefferson County[1]													
2	Iowa, 1899, five counties	25	221	$26.34	4,097	182		$1.28	$7.38	$0.642	$0.145		20	5
3	Ohio, 1899-1900, five counties east[1]													
4	New York, 1900, Delaware and Otsego Counties	13	221	31.92	3,898	208		1.23	7.34	.819	.153		11	2
5	Pennsylvania, 1901, Susquehanna County	30	398	33.93	4,414			1.38	12.89	.769			27	3
6	Wisconsin, 1901, Dunn County[1]													
7	New York, 1901-2, Onondaga County	26	308	32.04	4,645	216		1.39	12.50	.69	.149		20	6
8	New York, 1901-2, Bainbridge creamery	7	108	41.00	5,366			1.39	15.99	.764			7	0
9	Wisconsin, 1901-2, creamery and cheese factory[1]													
10	New York, 1901-2, Onondaga Milk Association	31	713	45.19	5,598			1.34	15.30	.807			24	7
11	Indiana, 1902-3, Marshall County	6	34	24.06	4,133		181.0	1.46	11.07	.582		$0.133	6	0
12	Ohio, 1903, Geauga County, cheese factory	22	221	29.45	5,585			1.75	22.09	.527			22	0
13	Ohio, 1904, Lorain and Medina Counties	2	15	28.00	4,736	293		1.71	20.02	.591	.096		2	0
14	Pennsylvania, 1904, Wayne and Franklin Counties	12	122	30.17	3,850	179		1.10	3.02	.784	.169		8	4
15	Connecticut, 1904, Andover creamery	6	83	38.60			182.0	1.31	11.97			.212	6	0
16	Vermont, 1904, central and northern	11	189	37.36			205.1	1.25	9.34			.182	10	1
17	Minnesota, 1904, creamery	65	638	25.52			173.0	1.36	9.26			.147	60	5
18	Wisconsin, 1905, Waukesha County	7	98	29.96		254		1.73	21.87		.118		7	0
19	New York, 1904-5, Delaware County	18	549	39.88	4,162		202.1	1.50	19.94	.958		.148	18	0
20	Michigan, 1905, Butler and Jackson Counties	37	358	32.21	4,432		193.0	1.39	12.56	.726		.167	31	6
21	New York, 1906, Ellisburg	17	340	39.18	5,513			1.59	23.12	.71			17	0
22	Iowa, 1906, three counties northeast	50	559	28.02			178.5	1.48	13.45			.157	45	5
23	New Hampshire, 1906, creamery	20	170	36.95			188.7	1.19	7.02			.196	19	1
24	Massachusetts, 1907, central and western	19	154	36.53			165.8	1.12	4.38			.22	11	8
25	Illinois, 1907, three counties northwest	27	416	32.48			180.0	1.53	17.21			.19	27	0
26	New York, 1908, Bainbridge, second time	13	287	49.08	5,380			1.62	30.39	.912			13	0
	Total	464	6,202										411	53
	Average			34.78	4,809	207	185.0	1.42	14.54	.775	.146	.175		

[1] Reading not reported.

SUMMARY H.

Herds whose owners do not read dairy literature.

Serial No.	Location and date of canvass.	Number of herds.	Number of cows.	Yearly cost of feed per cow.	Pounds of milk yearly per cow.	Pounds of butter yearly per cow.	Pounds of butter fat yearly per cow.	Returns for $1 worth of feed.	Net profit per cow yearly.	Food cost of milk per 100 pounds.	Food cost of butter per pound.	Food cost of butter fat per pound.	Profitable herds.	Unprofitable herds.
1	Wisconsin, 1899, Jefferson County[1]													
2	Iowa, 1899, five counties	75	661	$24.87	3,141	135		$1.03	$0.75	$0.791	$0.185		42	33
3	Ohio, 1899-1900, five counties east[1]													
4	New York, 1900, Delaware and Otsego Counties	67	1,143	31.66	3,505	180		1.03	.95	.903	.176		32	35
5	Pennsylvania, 1901, Susquehanna County	20	265	31.80	3,218			1.07	2.23	.988			12	8
6	Wisconsin, 1901, Dunn County[1]													
7	New York, 1901-2, Onondaga County	54	640	29.13	3,581	165		1.14	4.08	.813	.177		33	21
8	New York, 1901-2, Bainbridge creamery	44	682	37.61	3,546			.93	−2.44	1.061			20	24
9	Wisconsin, 1901-2, creamery and cheese factory[1]													
10	New York, 1901-2, Onondaga Milk Association	14	309	41.21	4,629			1.20	8.24	.89			11	3
11	Indiana, 1902-3, Marshall County	44	248	25.36	3,640		159.0	1.22	5.58	.691		$0.159	33	11
12	Ohio, 1903, Geauga County, cheese factory	24	243	26.54	3,567			1.19	5.04	.744			16	8
13	Ohio, 1904, Lorain and Medina Counties	31	226	26.48	3,524	179		1.05	1.24	.751	.148		19	12
14	Pennsylvania, 1904, Wayne and Franklin Counties	51	433	29.74	3,027	142		.88	−3.57	.982	.21		15	36
15	Connecticut, 1904, Andover creamery	11	72	36.09			123.0	.89	−3.97			.293	3	8
16	Vermont, 1904, central and northern	38	658	36.00			134.6	.80	−7.20			.267	5	33
17	Minnesota, 1904, creamery	35	353	23.80			99.2	.86	−3.21			.24	6	29
18	Wisconsin, 1905, Waukesha County	25	346	29.83		190		1.30	8.95		.157		23	2
19	New York, 1904-5, Delaware County	33	659	38.37	3,718		174.0	1.34	13.05	1.032		.22	31	2
20	Michigan, 1905, Butler and Jackson Counties	30	225	33.00	3,888		168.0	1.19	6.27	.849		.196	20	10
21	New York, 1906, Ellisburg	24	416	38.26	4,537			1.34	13.01	.845			19	5
22	Iowa, 1906, three counties northeast	46	463	27.70			121.9	1.01	.27			.227	26	20
23	New Hampshire, 1906, creamery	22	187	34.59			130.3	.73	−9.34			.265	1	21
24	Massachusetts, 1907, central and western	10	84	33.60			112.4	.87	−4.37			.299	1	9
25	Illinois, 1907, three counties, northwest	32	432	32.31			110.0	.94	−1.94			.30	13	19
26	New York, 1908, Bainbridge, second time	23	377	43.70	3,261			1.02	.87	1.34			11	12
	Total	753	9,122										392	361
	Average			35.00	3,584	165	136.7	1.05	1.85	.918	.177	.288		

[1] Reading not reported.

SUMMARY I.

Herds most profitable.[1]

Serial No.	Location and date of canvass.	Number of herds.	Number of cows.	Yearly cost of feed per cow.	Pounds of milk yearly per cow.	Pounds butter yearly per cow.	Pounds of butter fat yearly per cow	Returns for $1 worth of feed.	Net profit per cow yearly.	Food cost of milk per 100 pounds.	Food cost of butter per pound.	Food cost of butter fat per pound.	Herds of dairy type.	Herds fed silage.	Herds having good stables.	Owners read dairy literature.
1	Wisconsin, 1889, Jefferson County..........	10	149	$28.60	5.778	292	....	$1.92	$26.31	$0.494	$0.098	....	10	3	9	N.
2	Iowa, 1899, five counties....................	10	136	27.20	5.358	285	....	2.00	27.20	.507	.096	....	9	N.	N.	5
3	Ohio, 1899–1900, five counties, eastern.......	15	163	25.00	4,680	259	....	2.14	28.50	.534	.097	....	15	12	10	N.
4	New York, 1900, Delaware and Otsego Counties..................................	10	140	34.60	....	294	....	1.52	17.99	....	.117	....	10	4	8	3
5	Pennsylvania, 1901, Susquehanna County..	10	172	35.00	5,178	....	....	1.67	23.45	.675	....	....	8	6	8	10
6	Wisconsin, 1901, Dunn County............	10	123	25.10	5,918	276	....	1.98	24.61	.424	.09	....	7	N.	N.	N.
7	New York, 1901–2, Onondaga County......	10	109	26.50	5,544	256	....	1.97	25.75	.476	.103	....	8	N.	5	7
8	New York, 1901–2, Bainbridge creamery....	10	146	38.30	5,389	....	....	1.43	16.66	.71	....	....	7	5	7	9
9	Wisconsin, 1901–2, creamery and cheese factory..................................	10	157	31.50	5,559	259	....	1.61	19.22	.568	.121	....	8	6	N.	N.
10	New York, 1901–2, Onondaga Milk Association..................................	10	203	45.70	7,684	....	....	1.81	36.95	.594	....	....	5	N.	9	9
11	Indiana, 1902–3, Marshall County..........	10	67	24.40	5,138	....	229.0	1.82	20.00	.474	....	$0.106	8	N.	N.	N.
12	Ohio, 1903, Geauga County, cheese factory..	10	127	30.25	6,830	....	....	2.15	34.80	.443	....	....	10	4	5	9
13	Ohio, 1904, Lorain and Medina Counties....	10	74	26.74	4,884	281	....	1.66	17.75	.547	.096	....	8	4	7	9
14	Pennsylvania, 1904, Wayne and Franklin Counties..................................	10	65	29.90	4,384	205	....	1.36	10.90	.68	.145	....	7	N.	1	4
15	Connecticut, 1904, Andover creamery......	5	53	38.67	....	....	201.2	1.41	15.95	....	....	.192	5	N.	1	3
16	Vermont, 1904, central and northern........	10	243	38.37	....	....	231.2	1.39	15.15	....	....	.166	10	4	8	6
17	Minnesota, 1904, creamery................	10	129	29.54	....	....	258.0	1.83	24.66	....	....	.115	7	2	8	10
18	Wisconsin, 1905, Waukesha County........	8	104	29.75	....	274	....	1.91	27.06	....	.108	....	N.	N.	N.	N.
19	New York, 1904–5, Delaware County.......	10	277	40.64	5,128	....	260.0	1.86	34.93	.792	....	.156	7	N.	10	9
20	Michigan, 1905, Butler and Jackson Counties.	10	96	27.30	5,434	....	237.7	2.11	29.94	.504	....	.115	5	4	5	8
21	New York, 1906, Ellisburg.................	10	152	32.13	5,715	....	....	1.99	32.01	.569	....	....	7	7	8	3
22	Iowa, 1906, three counties, northeast........	25	273	28.17	....	....	209.7	1.74	20.83	....	....	.127	N.	N.	N.	N.
23	New Hampshire, 1906, creamery...........	10	118	38.30	....	....	213.3	1.31	12.11	....	....	.179	9	3	9	7
24	Massachusetts, 1907, central and western...	5	47	40.20	....	....	228.0	1.43	17.50	....	....	.185	4	N.	4	5

25	Illinois, 1907, three counties, northwestern..	10	363	32.48	....	....	237.7	2.01	32.93	....	....	.138	7	4	8	7
26	New York, 1908, Bainbridge, second time..	10	162	52.45	6,582	....	....	1.88	46.41	.796	....	....	10	4	10	3
	Total....................................	268	3,848	....	....	....	....	....	....	....	....	....	191	72	140	126
	Average..................................	....	....	33.66	5,690	271	234.0	1.78	26.18	.595	.105	.145	....	....	....	....
	Percentage...............................	....	....	....	....	....	....	....	....	....	....	....	81	46	72	70

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[1] All herds in this table are profitable. "N" stands for not reporting. "Percentage" means percentage of the affirmative class indicated, among the total reported regarding the feature mentioned. For instance, of the owners reported as either reading or not reading, 70 per cent do read dairy literature. Not all the owners were reported in regard to this feature; some canvasses failed to consider the matter of reading, while other canvasses ignored other features.

SUMMARY J.

Herds least profitable.[1]

Serial No.	Location and date of canvass.	Number of herds.	Number of cows.	Yearly cost of feed per cow.	Pounds of milk yearly per cow.	Pounds of butter yearly per cow.	Pounds of butter fat yearly per cow.	Returns for $1 worth of feed.	Net profit per cow yearly.	Food cost of milk per 100 pounds.	Food cost of butter per pound.	Food cost of butter fat per pound.	Profitable herds.	Unprofitable herds.	Herds of dairy type.	Herds fed silage.	Herds in good stables.	Owners read dairy literature.
1	Wisconsin, 1899, Jefferson County.....	10	254	$29.50	3,930	175	....	$1.09	$2.60	$0.75	$0.168	....	8	2	1	1	1	N.
2	Iowa, 1899, five counties..............	10	123	26.00	2,265	89	....	0.65	– 9.10	1.14	.293	....	0	10	0	0	N.	2
3	Ohio, 1899–1900, five counties, eastern.	15	119	27.00	2,850	147	....	1.09	2.43	.968	.184	....	12	3	1	3	0	N.
4	New York, 1900, Delaware and Otsego Counties..............................	10	140	33.80	....	132	....	.75	– 8.32	....	.256	....	0	10	1	1	1	0
5	Pennsylvania, 1901, Susquehanna County..............................	10	149	33.21	2,614	....	....	.82	– 5.98	1.27	....	....	0	10	0	2	1	2
6	Wisconsin, 1901, Dunn County........	10	134	28.80	3,755	174	....	1.08	2.28	.767	.165	....	9	1	0	N.	N.	N.
7	New York, 1901–2, Onondaga County..	10	94	32.60	2,432	113	....	.63	–12.06	1.34	.288	....	0	10	0	N	0	1
8	New York, 1901–2, Bainbridge creamery	10	146	36.60	2,303	....	....	.60	–14.53	1.58	....	....	0	10	1	2	1	0
9	Wisconsin, 1901–2, creamery and cheese factory..............................	10	142	31.80	3,237	141	....	.85	– 4.84	.985	.225	....	0	10	2	0	N.	N.
10	New York, 1901–2, Onondaga Milk Association..............................	10	260	47.90	3,457	....	....	.77	–11.08	1.385	....	....	0	10	1	2	8	7
11	Indiana, 1902–3, Marshall County.....	10	76	26.80	2,561	....	120.0	.86	– 3.72	1.046	....	$0.223	0	10	0	0	N.	0
12	Ohio, 1903, Geauga County, cheese factory..............................	10	98	27.26	2,835	....	....	.90	– 2.64	.961	....	....	2	8	1	0	3	0
13	Ohio, 1904, Lorain and Medina Counties..............................	10	83	28.20	2,845	135	....	.71	– 8.22	.991	.208	....	0	10	3	1	5	0
14	Pennsylvania, 1904, Wayne and Franklin Counties..............................	10	92	32.83	2,384	109	....	.55	–14.70	1.37	.301	....	0	10	0	0	0	0
15	Connecticut, 1904, Andover creamery.	5	33	36.87	....	....	109.1	.75	– 9.37	....	....	.337	0	5	0	0	0	0

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[1] "N" stands for not reporting. "Percentage" means percentage of the affirmative class indicated, among the total reported regarding the feature mentioned. For instance, of the owners reported as either reading or not reading, 26 per cent do read dairy literature. Not all the owners were reported in regard to this feature; some canvasses failed to consider the matter of reading, while other canvasses ignored other features.

SUMMARY J—Continued.

Herds least profitable—Continued.

Serial No.	Location and date of canvass.	Number of herds.	Number of cows.	Yearly cost of feed per cow.	Pounds of milk yearly per cow.	Pounds of butter yearly per cow.	Pounds of butter fat yearly per cow.	Returns for $1 worth of feed.	Net profit per cow yearly.	Food cost of milk per 100 pounds	Food cost of butter per pound.	Food cost of butter fat per pound.	Profitable herds.	Unprofitable herds.	Herds of dairy type.	Herds fed silage.	Herds in good stables.	Owners read dairy literature.
16	Vermont, 1904, central and northern..	10	146	$36.75	....	....	92.8	$0.54	−$16.90	....	....	$0.40	0	10	0	1	0	0
17	Minnesota, 1904, creamery............	10	103	24.65	....	....	82.2	.70	− 7.40	....	....	.30	0	10	0	0	5	1
18	Wisconsin, 1905, Waukesha County...	8	127	31.81	....	161	....	1.02	0.63	....	$0.198	....	6	2	0	N.	N.	0
19	New York, 1904–5, Delaware County..	10	208	36.17	2,734	....	132.6	1.00	.07	$1.32	....	.272	7	3	3	N.	0	3
20	Michigan, 1905, Butler and Jackson Counties........................	10	84	43.75	2,952	....	118.5	.62	− 16.60	1.48	....	.37	0	10	4	0	0	2
21	New York, 1906, Ellisburg............	9	133	39.65	3,051	....	....	.80	− 7.71	1.30	....	....	0	9	0	2	3	0
22	Iowa, 1906, three counties, northeast..	25	257	28.92	....	....	100.0	.78	− 6.33	....	....	.29	0	25	1	0	16	0
23	New Hampshire, 1906, creamery......	10	99	34.00	....	....	79.2	.51	− 16.46	....	....	.43	0	10	3	1	1	0
24	Massachusetts, 1907, central and western..............................	5	47	34.00	....	....	91.5	.75	− 8.54	....	....	.371	0	5	2	N.	1	1
25	Illinois, 1907, three counties, northwest.	10	139	31.10	....	....	84.0	.74	− 7.93	....	....	.37	0	10	0	0	4	3
26	New York, 1908, Bainbridge, second time..............................	10	173	43.60	2,662	....	....	.83	− 7.19	1.64	....	....	0	10	0	1	3	0
	Total........................	267	3,459	....	....	....	....	....	....	....	....	....	44	223	24	17	53	22
	Average......................	....	....	33.76	2,973	143	102.2	.80	− 6.70	1.167	.211	.321	....	....	....	....	....	....
	Percentage...................	....	....	....	....	....	....	....	....	....	....	....	....	....	10	11	27	12

COMPARISON OF MOST PROFITABLE AND LEAST PROFITABLE HERDS.

In comparing the most profitable and least profitable herds in the two preceding tables we bring together the most instructive features of this investigation. The following points may be noted:

1. Cows of good dairy type are found in only 17 per cent of the least profitable herds, whereas they occur in 71 per cent of the most profitable herds.
2. Silage is fed to only one-third as many of the least profitable herds as of the most profitable herds.
3. Good stables are only one-half as common for the least profitable herds as for the most profitable herds.
4. The reading of dairy literature is reported 44 per cent less often among owners of the least profitable herds than among owners of the most profitable herds.

GENERAL SUMMARY BY FEATURES.

The following statement summarizes the various features detailed in the preceding tables, showing in each case the average total results for all the canvasses, also the differences in favor of the more progressive dairymen.

SUMMARY K.

General summary by features.

Features.	Number of herds.	Number of cows.	Yearly cost of feed per cow.	Pounds of milk yearly per cow.	Pounds of butter yearly per cow.	Pounds of butter fat yearly per cow.	Returns for $1 worth of feed.	Net profit per cow yearly.	Food cost of milk per 100 pounds.	Food cost of butter per pound.	Food cost of butter fat per pound.	Profitable herds.	Unprofitable herds.
Total of canvasses	2,163	28,447	$33.43	4,213	196	158.4	$1.24	$8.11	$0.802	$0.148	$0.213	1,531	632
Herds of good dairy type	652	9,365	33.95	5,104	240	189.0	1.51	17.38	.656	.122	.185	597	55
Herds lacking dairy type	685	8,104	32.01	3,550	162	138.2	1.06	2.03	.908	.178	.23	379	306
Difference in favor of dairy type	......	......	−1.94	1,554	78	50.8	0.45	15.35	.252	.056	.045	......	....
Herds fed silage	329	6,689	34.98	4,760	230	181.8	1.39	13.50	.747	.129	.189	282	47
Not known to be silage fed	1,834	21,758	32.95	4,045	186	151.2	1.20	6.46	.822	.155	.222	1,249	585
Difference in favor of silage	......	......	−2.03	715	44	30.6	.19	7.04	.075	.026	.033	......	....
Herds in good stables	639	9,506	34.53	4,793	240	180.0	1.41	14.12	.75	.124	.187	553	86
Herds in poor stables	323	3,775	32.53	3,514	164	130.0	1.01	0.23	.927	.177	.266	153	170
Difference in favor of good stables	......	......	−2.00	1,279	76	50.0	.40	13.89	.177	.053	.079	......	....
Herds whose owners read dairy literature	464	6,202	34.78	4,809	207	185.0	1.42	14.54	.775	.146	.175	411	53
Herds of nonreaders	753	9,122	35.00	3,584	165	136.7	1.05	1.85	.918	.177	.288	392	361
Difference in favor of readers	......	......	0.22	1,225	42	48.3	.37	12.69	.143	.031	.113	......	....
Herds most profitable	268	3,848	33.66	5,690	271	234.0	1.78	26.18	.595	.105	.145	268	0
Herds least profitable	267	3,459	33.76	2,973	143	102.2	.80	−6.70	1.167	.211	.321	44	223
Difference in favor of most profitable	......	......	.10	2,717	128	131.8	.98	32.88	.572	.106	.176	......	....

CONCLUSIONS.

As has been previously observed, wrong inferences might be drawn both from the data upon which this bulletin is based and from the summaries compiled from this data had the reader not been informed in regard to the manner in which the data was collected. We learn, for example, that the average cow of the 639 herds stabled comfortably returned the owner an annual profit of $14.12, while the average cow of the 323 herds in poor stables produced during one year only 23 cents more than the cost of her feed. Here we can not believe that the difference is due wholly to the stabling, but are justified in assuming that the cows comfortably stabled were, on the whole, better individuals and had better feed and care. Just what proportion of the difference we should credit to any one of these controlling factors we have no means of determining.

1. From the 329 herds reported as having been fed silage, numbering 6,689 cows, $1.39 was received for each dollar's worth of feed consumed, compared with $1.20, the average return from the 21,758 cows not reported upon with reference to whether silage formed a part of their rations.

Comparing herds fed silage with those not reported to be so fed (the larger part of which probably did not have silage and which may be regarded as representing the actual common run of dairy herds in the United States), we find that the ratio of profitable to unprofitable herds among the silage fed is to that ratio among those not reported as 2.8 is to 1; or that the probabilities of making a profit are nearly three to one in favor of the silage feeder as compared with the average dairy farmer.[1]

2. In the 652 herds, comprising 9,365 cows, reported as being of good dairy type, a cow paid her owner an average annual profit of $17.38; while 685 herds, numbering 8,104 cows, not of dairy type, returned a profit of $2.03 cents per head—the word "profit" here, as elsewhere in this bulletin, meaning the excess of receipts over value of feed.

We find, further, that the ratio of profitable to unprofitable herds is nine times as great among herds of good dairy type as it is among herds lacking good dairy type.[1]

3. The owners of 464 herds, numbering 6,202 cows, were registered as readers of dairy papers. This group reported the cost of feed to be $34.78 per cow, and secured $1.42 for each dollar spent for feed, or a profit of $14.54 per cow.

The cow owners whose minds were not illuminated nor their methods improved through the influence of dairy literature controlled

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[1] For explanation in regard to comparison of ratios, see footnote to canvass 2, page 14.

753 herds, composed of 9,122 cows. The feed of the cows cost them a little less, viz, $35, but they made an average annual profit of only $1.85 per cow. Of these nonreaders, 48 per cent actually lost money in following the dairy business.

The records also show that the ratio of profitable to unprofitable herds is seven times as great among readers as it is among those who do not read.[1]

4. The number of herds reported as occupying good stables was 639, comprising 9,506 head. These returned their owners a net profit of 41 cents on each dollar's worth of feed ($1.41 return for $1), or $14.12 profit per head for the year; while the 323 poorly stabled herds, containing 3,775 cows, returned to their owners only 23 cents more than the cost of their feed.

The ratio of profitable to unprofitable herds is more than seven times as great among herds in good stables as it is among herds in poor stables.[1]

It is the strongest confirmation of the trustworthiness of arguments if the methods which they are held to prove work out successfully in practice. It will be a source of assurance to the instructor in dairying to find that his teachings are useful when applied to business; and, on the other hand, the farmer can with confidence put such theories into practice if he finds that other farmers have done so with profit.

The conclusions reached by consideration of the facts presented in these canvasses show that what is theoretically sound in dairy instruction is also practically profitable in the actual business of dairy farming.

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[1] For explanation in regard to comparison of ratios see footnote to canvass 2, page 14.

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Issued June 30, 1913.

U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ANIMAL INDUSTRY.—BULLETIN 165.

A. D. MELVIN, CHIEF OF BUREAU.

THE MANUFACTURE OF CHEESE OF THE CHEDDAR TYPE FROM PASTEURIZED MILK.

BY

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Animal Industry,
Washington, D. C., January 30, 1913.

Sir: I have the honor to transmit for publication as a bulletin of this bureau the accompanying manuscript entitled "The Manufacture of Cheese of the Cheddar Type from Pasteurized Milk," by Prof. J. L. Sammis, of the College of Agriculture, University of Wisconsin, and Mr. A. T. Bruhn, expert cheese maker in the Dairy Division of this bureau. The work herein described was conducted at Madison, Wis., in cooperation between the Dairy Division and the Wisconsin Agricultural Experiment Station.

The Dairy Division has been represented at Madison by L. D. Bushnell, Alfred Larson, and Miss Alice C. Evans, bacteriologists, in succession; S. K. Suzuki and E. F. Flint, chemists, and J. W. Moore, F. W. Laabs, and A. T. Bruhn, expert cheese makers, in succession, all of whom have assisted at various times in this work. The Wisconsin Station has been represented by Prof. Sammis, who from the beginning has had charge of the cooperative experiments in the manufacture of the Cheddar type of cheese from pasteurized milk.

The comparison of this cheese with that made from raw milk by the regular factory method has been systematically and thoroughly carried out under a variety of conditions by the use of duplicate vats of milk, one of these being pasteurized in each instance. During 1910 and 1911, especially in the latter year, the new process was perfected and a large quantity of the pasteurized cheese was made under commercial conditions and placed upon the open market. The results are fully described, also the process of making the cheese, and it is shown that the use of pasteurized milk is highly satisfactory and economical. As pathogenic bacteria have been found to survive for several months in cheese made from raw milk, the pasteurization of milk in making cheese is also desirable for the protection of the health of the consumer.

Respectfully,

A. D. Melvin,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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THE MANUFACTURE OF CHEESE OF THE CHEDDAR TYPE FROM PASTEURIZED MILK.

INTRODUCTORY.

THE NEED FOR A NEW METHOD OF CHEESE MAKING.

Economy of time and labor and improved quality and uniformity of the cheese produced make the large cooperative factory more profitable to farmers than the small factory, provided they retain the control, if not the complete ownership, of it. There are two objections sometimes raised against the replacement of four or five small cheese factories in a neighborhood by one large, better-equipped, better-manned, and more economical cheese factory, namely: First, that by present factory methods cheese makers could not make as good cheese from milk gathered over a large territory, because it would be longer on the road to the factory and therefore would not be so fresh as otherwise; second, farmers object to hauling milk a great distance, even to a good cheese factory.

The only way to get a large, first-class cheese factory located within a short distance of a sufficient milk supply is to centralize the latter—that is, to keep as many of the best cows on every farm as the land will support. Until this is done there will be many factories which must draw milk from a large area. Some modification of present cheese-factory methods is needed by which milk from a large territory can be successfully handled.

The great amount of inferior cheese on the market and the lack of uniformity which characterizes the product of the present cheese factory of average size is due primarily to the variable quality of the milk supply from different farms, especially as to the presence of dirt and bacteria, which produce faulty flavors and textures in great variety, and to the variable ripeness or acidity of the milk received from day to day, depending upon the care given to it on the farm, its age, etc.

The immediate effect of these conditions is that cheese makers in their effort to produce cheese of uniform quality from milk of variable quality must necessarily use methods which vary from day to day and from factory to factory. Under this system each vat of milk must be watched carefully at every stage of its manufacture, and the cheese-making process must be hastened, or delayed, or modified every day, according to the cheese makers' judgment. The yield of cheese also varies from day to day, depending upon the quality of the milk and the method used in handling it.

The ideal conditions for cheese making require an absolutely clean and perfect milk supply, and this can not be realized until methods of milk production on the farm are vastly improved. In the meantime a process for treating milk daily at the factory so as to bring it into practically uniform condition for cheese making purposes is needed. Such a process should include means for stopping the ripening and the growth of harmful bacteria, etc., in the milk as soon as it is received at the factory, in order that it may be ripened with a clean starter, in a uniform manner, daily. The process should be applicable to milk of any degree of ripeness which can properly be accepted as fit for cheese making from a sanitary standpoint. When milk is thus brought by a preliminary treatment into uniform condition at the factory, both as to acidity and as to bacterial content, the present variable and irregular methods of making cheese could probably be replaced by a routine process, operated upon a fixed time schedule without variation from day to day. As a result, it is to be expected that the uniformity, quality, and yield of cheese would be much improved as compared with that obtained by the older methods. In many other lines of manufacture in recent years preliminary processes have been devised for bringing raw materials into uniform condition before they enter the manufacturing process, and improved products, increased economies, and larger output and profits have resulted. It is desirable that the same general methods of improvement which have been used with success in other lines be applied also to the cheese-making industry.

FAULTS TO BE CORRECTED IN MILK FOR CHEESE MAKING.

The defects most commonly met with in milk, which must be corrected by such a preparatory process as that contemplated, are of bacterial origin. A variable content of lactic-acid bacteria causes milk when received at the factory to exhibit different degrees of acidity and also causes the subsequent development of acid in the milk and curd, while in the vat, to go on at varying rates. On account of the important influence which acidity has upon the rate at which whey is expelled from curd, as pointed out in a previous bulletin,[1] it may well be said that this is the leading controlling factor in the manufacture of American Cheddar cheese. Therefore it is of prime importance to secure milk of uniform acidity with which to begin cheese making, and also to provide for subsequent acid development at a practically fixed rate every day in order to avoid the present troubles due to irregular acid formation.

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[1] Sammis, J. L., Suzuki, S. K., and Laabs, F. W. Factors controlling the moisture content of cheese curds. U. S. Department of Agriculture, Bureau of Animal Industry, Bulletin 122. Washington, 1910. See p. 29.

Those bacteria which produce gas or tainted, unclean flavors are all too common in milk, and are the cause of much trouble in the cheese factory. Bacteria which produce diseases such as tuberculosis, typhoid fever, diphtheria, dysentery, etc., have often been found in milk, although it is difficult to prove that any person ever contracted these diseases from eating cheese. These and other bacterial infections of raw cream and milk for city trade are usually combated by pasteurization; this is true, likewise, in butter making, and with skim milk when used for feeding stock. It seems reasonable, therefore, that any process, such as pasteurization, which will kill the acid, taint, gas, and disease-producing organisms in milk would also improve the quality of the cheese produced therefrom.

THE NECESSITY FOR THE PASTEURIZATION OF MILK FOR CHEESE MAKING.

In view of the possible presence of tubercle bacilli in market cheese, Mohler[1] in 1908 recommended the "pasteurization of the milk in order to make the cheese perfectly safe." Mohler, Washburn, and Doane[2] prepared and studied cheese from milk to which cultures of bacillus tuberculosis had been added. They inoculated guinea pigs with such cheese at various periods of time after its manufacture and found that—

> Advancing cases of generalized tuberculosis were developed (in guinea pigs) by means of inoculation of cheese 220 days old, and that slight tubercular lesions were caused by the injection of an emulsion of cheese when 261 days old."

They add:

> If it is possible to use pasteurized milk in the manufacture of cheese without injuring the product a simple solution of the problem is offered to the cheese manufacturer in the process known as pasteurization.

These authors also give a brief résumé of previous work on this subject in Europe and America.

It is evident that the bacillus of tuberculosis not only retains its life but also its virulence in cheese for a considerable period of time, and that cheese made from raw, unpasteurized milk should therefore be considered as a possible carrier of tubercle bacilli.

There is a strong tendency at the present time to cure American cheese more rapidly than in the past, so that it commonly reaches

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[1] Mohler, John R. Conditions and diseases of the cow injuriously affecting the milk. U. S. Treasury Department, Public Health and Marine-Hospital Service, Hygienic Laboratory, Bulletin 41. Washington, 1908. See p. 495.

[2] Mohler, John R., Washburn, Henry J., and Doane, C. F. The viability of tubercle bacilli in cheese, Twenty-sixth Annual Report of the Bureau of Animal Industry, U. S. Department of Agriculture (1909), pp. 187–191. Washington, 1911.

In Denmark a kind of cheese is made from pasteurized skim milk to which about 10 per cent of buttermilk is added so as to bring the acidity up to about 0.21 per cent just before adding rennet.[1]

In 1907 Dean [2] stated as a result of experiments in the use of calcium chlorid with pasteurized milk for cheese making "the coagulum was of a soft, weak nature and the cheese tended to be soft and porous." He also added 1½ to 3 per cent of bacterial starters to milk pasteurized at 180° F. and ripened some time before adding rennet. The rennet coagulated the milk, but the curd was weak in body. He noted an increased yield of cheese, but the cheese tended to be open and weak in body and texture. He adds:

> On the whole the results are not very satisfactory and we shall require more light on the subject of making pasteurized milk cheese before we could recommend the method to Canadian cheese makers.

In 1910 C. A. Publow [3] mentioned briefly some experiments in making cheese from pasteurized milk, adding to each 100 pounds of milk 2 cubic centimeters of a 25 per cent solution of calcium chlorid and 2 or 3 pounds of bacterial starter. The details of the method and the opinions of cheese judges other than the author respecting the product are not published. At this station in previous years efforts have been made to obtain good American cheese from pasteurized milk with the aid of calcium chlorid, but without success.

DIFFICULTIES MET IN MAKING CHEESE FROM PASTEURIZED MILK.

Pasteurization of milk prevents or greatly delays subsequent coagulation with rennet. The curd from such milk when finally cut into cubes expels moisture with much greater difficulty than a raw-milk curd, probably because of some chemical change produced in the casein by the heat of pasteurization. Rapid acid formation by bacterial action which occurs in raw milk and raw-milk curds does not occur in the pasteurized material. The presence of a moderate amount of lactic acid in raw-milk curds greatly hastens the separation of whey from the curd, and the lack of acid development in pasteurized-milk curds is another condition favoring the retention of excessive moisture in the curd and cheese.

The addition of calcium chlorid to milk which has been pasteurized is known to restore in a measure the coagulability of the milk with rennet, but we have observed, as Publow[4] points out, that, although coagulation begins in about five minutes, "the curd does not become firm enough for cutting in the usual time and should not be cut before it is firm." Although the addition of calcium chlorid restores the coagulability with rennet, it does not correct the acidity and the other difficulties mentioned above as being caused by pasteurization. The lack of acidity in such curd might be supplied by adding starter to the pasteurized milk and ripening for several hours before starting the cheese making, but the resulting loss of time would prohibit this practice in factories. Where both starter and calcium chlorid are added to milk after pasteurization, as suggested by Publow, and the cheese-making process is begun at once without waiting for ripening, the daily variations in natural acidity of the milk used produce corresponding variations in the moisture content of the cheese which affect its quality. (See Table 1.)

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[1] Decker, John W. Cheese making. 5th edition. Madison, Wis., 1909. See p. 194.

[2] Dean, H. H. Experiments in cheese making. Ontario Agricultural College, Thirty-third Annual Report (1907). Toronto, 1908. See p. 120.

[3] Publow, Charles A. Fancy cheese in America. Chicago, 1910. See p. 20.

[4] Loc. cit. See p. 21.

What is needed in place of calcium chlorid for addition to pasteurized milk is something which will not only restore the coagulability with rennet, but which will also bring up the acidity without delay to a sufficiently high percentage to induce reasonably rapid and complete separation of whey from curd. A uniform acidity is necessary daily so as to avoid daily variations in moisture content of cheese.

DIFFICULTIES OVERCOME BY ACIDULATION OF PASTEURIZED MILK.

The substance which has been found to meet all of the foregoing requirements and which appears to be unobjectionable from all standpoints is hydrochloric acid. While it might appear impracticable at first glance to acidulate milk in large quantities daily at a factory, yet upon trial this is found to be entirely practicable; and it has now been done almost daily for nearly three years, without any trouble arising from coagulation of the milk with acid at any time.

In Table 1 is shown the moisture content of green cheese obtained on 12 days from pasteurized milk by the use of calcium chlorid in the proportions suggested by Publow (see p. 14) and by the use of hydrochloric acid, using always sufficient acid to raise the acidity of the milk to 0.25 per cent calculated as lactic acid. The milk used in the two vats was taken from the same receiving vat full of milk, after thorough mixing. It was all pasteurized alike and one-half was then treated with calcium chlorid and the other with hydrochloric acid. These were then made up into cheese separately and were sampled for moisture at the time the cheeses were dressed, after pressing one hour.[1] From the table it can be seen that whenever the acidity of the milk used was low (0.16 to 0.18 per cent) the moisture content of the cheese made with calcium chlorid was high (40 to 44.45 per cent), and when the acidity was high (0.21 to 0.23 per cent) the moisture content was low (38 to 40 per cent). But in all cases where hydrochloric acid was added instead of calcium chlorid the moisture content of the curd was 37.5 to 40 per cent, whether the natural acidity of the milk was high or low.

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[1] The correctness of this method of sampling cheese for the moisture test is demonstrated in the latter part of this bulletin.

TABLE 1.—*Comparison of moisture content and quality of cheese made with calcium chlorid and with hydrochloric acid.*

Date made.	Acidity of milk when pasteurized.	How made.	Moisture content of dressed cheese.	Score.		Criticism.	
				Flavor.	Texture.	Flavor.	Texture.
1911.	*Per ct.*		*Per cent.*				
Aug. 18	0.165	Calcium chlorid	42.25	38	26	Flat, pungent	Curdy, loose, weak.
Do	.165	Hydrochloric acid	37.70	41½	27½	Clean	Trifle loose.
Aug. 22	.165	Calcium chlorid	42.35	40	26	Flat, lacking	Weak, sticky.
Do	.165	Hydrochloric acid	38.80	41	27½	Clean and O. K	Trifle weak.
July 28	.17	Calcium chlorid	41.50	38	24	Lacks acid	Wet and sticky.
Do	.17	Hydrochloric acid	37.70	41½	28	Trifle acid	Trifle sticky.
Aug. 23	.175	Calcium chlorid	44.27	39½	25½	Low, lacking	Trifle weak.
Do	.175	Hydrochloric acid	39.20	40½	27	Trifle sharp	Do.
Aug. 24	.175	Calcium chlorid	44.27	37	25	Sour-milk flavor	Very loose, weak.
Do	.175	Hydrochloric acid	39.62	41	26½	Trifle sharp	Trifle weak.
Aug. 25	.175	Calcium chlorid	44.45	41½	26½	Clean and O. K	Sticky, loose, short.
Do	.175	Hydrochloric acid	39.02	41½	28	O. K	
Aug. 11	.185	Calcium chlorid	42.90	40	25	Bitter, lacks acid	Coarse, loose.
Do	.185	Hydrochloric acid	39.90	41½	28	O. K	
Sept. 4	.190	Calcium chlorid	41.50	39	26	Sweet, bitter	Weak, mechanical holes.
Do	.190	Hydrochloric acid	39.95	41½	27½	Acid aftertaste	Mechanical holes.
Aug. 17	.21	Calcium chlorid	39.20	41	26	Tastes salty	Weak and sticky.
Do	.21	Hydrochloric acid	39.62	41	26½	do	Loose, sticky.
Aug. 16	.21	Calcium chlorid	38.70	39	26½	Vinegar flavor	Sweet holes.
Do	.21	Hydrochloric acid	38.60	41½	27	Clean and O. K	Trifle loose.
Aug. 28	.22	Calcium chlorid	40.60	41	26½	Trifle bitter	Short, sticky.
Do	.22	Hydrochloric acid	39.95	41	27½	do	Trifle short.
Aug. 7	.31	do	39.05				
Aug. 10	.187	do	37.58				
Aug. 21	.215	do	38.67				
Average		Calcium chlorid	42.00	39.45	25.73		
Do		Hydrochloric acid	38.95	41.23	27.36		

From the above table it is evident that when milk is acidulated with hydrochloric acid after pasteurization, as in the new method, the moisture content of the green cheese is not affected by the ripeness of the milk before pasteurization and is quite constant between 37.5 and 40 per cent. This advantage does not attend the use of calcium chlorid. The daily variations of moisture content shown in column 4, which are between 37.5 and 40 per cent, are doubtless due to causes other than acidity, and did not noticeably affect the quality of the cheese. The scores and criticisms show that the cheese made with calcium chlorid was neither as uniform nor as good in quality as that made with hydrochloric acid.

The addition of hydrochloric or lactic acid to cream to raise its acidity without delay, preparatory to churning, was attempted by Babcock in 1888.[1] The addition of a commercial acid to raw milk to raise its acidity without waiting for bacterial action was suggested to the writer in 1905 by Dr. S. M. Babcock, chief chemist of the Wisconsin Experiment Station, and during the years 1905–6 the effort was made, following the suggestion of Dr. Babcock, to avoid the necessity for ripening milk for cheese making at the factory and to substitute for such ripening the addition of a commercial acid to the milk as soon as it was received. Immediately after acidulating the milk it was heated to 86° and rennet was added and the process completed in the usual manner. These experiments showed conclusively that a commercial acid such as hydrochloric acid can be added to milk without in any way damaging the quality of the cheese obtained. However, the quality of cheese obtained from overripe or tainted milk was not improved by the use of the acid, and it was concluded that acidulation alone does not offer sufficient advantages to warrant its recommendation to cheese makers. The addition of acids to pasteurized milk for cheese making was begun by the writer in 1907.

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[1] Babcock, S. M. Churning tests. Wisconsin Agricultural Experiment Station, Fifth Annual Report, 1888, p. 111–121. Madison, 1888. See p. 118. See also patent granted to Müller, Milch-zeitung, vol. 23, no. 19, p. 301, Bremen, May 12, 1894; also notes on this subject in same volume, pp. 425, 464, 701, 750.

Pasteurization and acidulation of milk appear to be complementary processes, each supplying what the other lacks and together forming the basis of an improved method of cheese making.

Since the use of calcium chlorid in pasteurized-milk cheese will not be referred to again in this paper, two other points will be mentioned here in which the use of hydrochloric acid is more advantageous. These are: First, that the hydrochloric acid curds always begin to thicken 6½ to 7 minutes after rennet is added, while with calcium chlorid the first visible coagulation occurs earlier if the milk used is very ripe and later if the milk is sweet, thus varying from day to day, as shown in Table 2. Second, the percentage of fat lost in the whey is on the average about 0.14 per cent greater in the method using calcium chlorid than when hydrochloric acid is used, as also shown in Table 2. This is probably because calcium chlorid curds are always more mushy and easier to break up in stirring than curds made with hydrochloric acid. The latter are really superior in this respect to curds obtained by the regular factory methods.

TABLE 2.—*Comparison of calcium chlorid with hydrochloric acid as to their effects on cheese made with pasteurized milk.*

Date.	Time required for visible coagulation after adding rennet.		Per cent of fat in whey at time of drawing whey and matting curd.		Acidity of milk used.
	Calcium chlorid.	Hydrochloric acid.	Calcium chlorid.	Hydrochloric acid.	
1911.	*Minutes.*	*Minutes.*	*Per cent.*	*Per cent.*	*Per cent.*
July 28	14	7	0.23	0.13	0.17
Aug. 11	15	7	.35	.14	.185
16	6	7	.16	.12	.21
17	4	7	.21	.14	.21
18	14	7	.32	.19	.165
22	14½	7	.32	.18	.165
23	18	7	.39	.20	.175
24	18	7	.42	.20	.175
25	16	7	.38	.16	.175
28	6½	7	.17	.13	.22
Average..	....	....	.295	.159	....

THE PASTEURIZATION PROCESS.

PASTEURIZATION IN A DISCONTINUOUS OR "HELD" PASTEURIZER.

In May, 1907, one day's milk supply was divided in two portions, one of which was made up by the regular method and the other was pasteurized for 18 minutes at 160° F. and acidulated with hydrochloric acid. The pasteurized vat gave the best-flavored cheese after curing, though it was inferior in texture to the other. On March 12 and 27, 1908, milk pasteurized at 140° for 20 minutes and then acidulated gave such good cheese that a systematic study of the combined process of pasteurization and acidulation was begun in July, 1908. Cheese was made from milk pasteurized at 140° F. for 20 minutes, either in a Potts pasteurizer or in the cheese vat, by running first steam and then cold water into the jacket. At the same time part of the milk supply after mixing and dividing was used for making cheese by the regular methods. The scores given to the two lots of cheese thus obtained are shown below:

TABLE 3.—*Comparison of flavor and texture of cheese made from raw milk and from milk pasteurized at 140° F. for 20 minutes.*

Date made.	Pasteurized cheese.		Regular make.	
	Flavor.	Texture.	Flavor.	Texture.
1908.				
July 16	38.3	26.2	36.2	27.8
17	40.0	27.0	38.5	26.25
18	41.7	27.5	39.25	27.0
20	40.8	26.3	37.3	26.75
21	41.2	26.0	41.2	26.2
22	41.3	26.8	38.0	26.75
23	40.8	26.7	39.5	26.5
24	41.0	27.25	38.3	26.25
31	40.25	26.25	36.5	26.5
Average..	40.59	27.00	38.30	26.66

The scoring was done by J. W. Moore and F. W. Laabs. In every case but one the pasteurized cheese had better flavor and there was little difference in texture between the two lots.

CONTINUOUS AND "HELD" PASTEURIZATION COMPARED.

On account of the large volume of milk which must be handled daily in a cheese factory, and the greater expense involved in providing arrangements of sufficient capacity for heating and cooling 5,000 to 7,000 pounds of milk at one time as compared with the small cost of a continuous pasteurizer, most of the later work was done with continuous pasteurizers. These can be used for handling any required volume of milk, a larger quantity simply necessitating a longer time for running. At the present time they are believed preferable for cheese-factory use over any form of intermittent pasteurizer yet devised. Good results had been obtained by pasteurization at 140° for 20 minutes, but since continuous pasteurization seemed the more practical factory method, it was determined to use both methods in comparison on the same milk for several days. On eight days, between July 16 and 24, 1908, half of the milk was pasteurized at 140° for 20 minutes and the other half at either 150°, 160°, or 170° in the continuous machine. The effectiveness of the two methods of pasteurization was judged from the increase in acidity observed in the whey within the time from cutting curd to drawing whey specified in each case.

TABLE 4.—*Increase of acidity after pasteurization by continuous and by held processes.*

Date.	Milk held at 140° for 20 minutes.		Milk pasteurized at 150°. Instantaneous.		Milk pasteurized at 160°. Instantaneous.		Milk pasteurized at 170°. Instantaneous.	
	Increase.	Time.	Increase.	Time.	Increase.	Time.	Increase.	Time.
1908.	*Per ct.*	*H. m.*	*Per ct.*	*H. m.*	*Per ct.*	*H. m.*	*Per ct.*	*H. m.*
July 16	0.11	2 57	....	....	0.055	3 0	....	....
17	.068	2 17	....	....	.03	2 59	....	....
18	.055	2 17	....	....	.03	2 46	....	....
20	.01	2 31	....	....	....	....	0.01	3 30
21	.02	2 19	....	....	....	....	.01	3 30
22	.03	2 21	....	....	....	....	.035	3 20
23	.078	2 10	....	....	....	....	.053	3 8
24	.018	2 30	0.01	2 40	....	....	....	....

From the above it can be seen that where milk is highly inoculated when raw, as on July 16, 17, 18, and 23, the acidity of the whey rose 0.05, 0.06, 0.07, and 0.11 per cent in about 2¼ hours after pasteurizing at 140° for 20 minutes, while it rose only about half as high in 3 hours after pasteurizing at 160° or 170° in the continuous machine.

A further substantial difference between curds from milk pasteurized on the one hand at 140° for 20 minutes and on the other at 160° in the continuous machine is that the former curds often become mellow and greased on the surface and leak white whey after milling, in this respect resembling some raw-milk curds. It was supposed at first, from analogy to ordinary factory methods, that the curd which became mellow and somewhat greased on the surface and which leaked more or less white whey was more likely to turn out well than the other, which was supposed to be lacking in acid or acid-forming bacteria. The observation was made that a curd from milk pasteurized at 170° and afterwards treated with 5 per cent starter did not become mellow in the least, while curds from the same day's milk pasteurized at 140° for 20 minutes and then treated with three-fourths per cent starter, became very mellow and abundantly greased before milling. It was judged unnecessary, thereafter, to wait for mellowness or any other evidence of bacterial action or acid development in a pasteurized-milk curd. If a sufficient proportion of starter has been added after pasteurization, it is perfectly certain that the bacteria are present in the curd, and will take part in the curing on the shelf. From this point of view the mellowness which the 140° curds occasionally exhibit is to be regarded as objectionable and as evidence of lack of uniformity between different days' make, and since this never occurs with milk pasteurized at 160° in the continuous machine the latter appears preferable.

The cause for the greater increase of acidity in whey after cutting curd from milk pasteurized at 140° for 20 minutes, as shown above, is no doubt the fact that the milk thus pasteurized contained more living, active bacteria than that pasteurized in the continuous machine. Samples were taken for bacteriological count in every case immediately after pasteurizing, and then three-fourths per cent of starter was added to each vat, followed immediately by rennet as soon as the vat could be heated. Bacterial counts were made on these samples by Mr. L. D. Bushnell, bacteriologist, as follows:

TABLE. 5.—*Number of bacteria per cubic centimeter in raw and pasteurized milk.*

Date.	Raw milk.	Pasteurized milk.		
		At 140° for 20 minutes.	In continuous machine.	
1908.	*Number per c. c.*	*Number per c. c.*	*Number per c. c.*	*° F.*
July 17	102,000,000	2,206,000	652,000	160
18	72,000,000	2,620,000	1,960,000	160
20	119,000,000	262,000	200,000	170
21	30,000,000	33,000	9,200	170
22	173,000,000	320,000	38,000	170
23	360,000,000	15,320,000	1,300,000	170
24	65,000,000	62,000	1,100,000	150

SELECTION OF BEST TEMPERATURE FOR PASTEURIZATION IN THE CONTINUOUS MACHINE.

The temperature selected should be high enough to insure that the ripening of the milk shall be uniformly checked daily, regardless of the bacterial content of the milk used, and it should not be so high as to injure the quality of the cheese. Tests were made as follows: On several days the milk supply after mixing was divided into four lots, one of which was made up by regular methods, the others were pasteurized at 140°, 150°, and 160° and made up in separate vats. The cheese after curing was examined by several expert cheese judges, including Messrs. U. S. Baer, Robert McAdam, H. J. Noyes, F. W. Laabs, and Gottlieb Marty, whose scores are given in Table 6:

TABLE 6.—*Quality of cheese made from raw milk and from milk pasteurized at different temperatures in the continuous-disk machine.*

Date.	Regular make.		Pasteurized at—					
			140° F.		150° F.		160° F.	
	Flavor.	Texture.	Flavor.	Texture.	Flavor.	Texture.	Flavor.	Texture.
1908.								
July 14	....	....	40.0	28.5	41.5	28.5	43.0	28.5
15	40.0	28.5	40.5	28.5	41.0	29.0	41.0	29.0
16	36.0	27.0	38.0	28.0	40.0	29.0	41.0	29.0
17	36.0	28.0	38.0	28.5	41.0	29.0	42.0	29.0
20	38.0	28.5	40.0	28.5	41.0	28.5	42.0	29.0
21	39.0	29.0	41.0	28.5	41.0	28.5	41.5	29.0
22	35.0	28.0	37.0	28.0	38.0	28.0	39.0	27.5
15	38.0	27.0	....	....	....	....	41.0	27.5
	40.0	26.0	....	....	....	....	44.0	28.0
	40.0	26.0	....	....	....	....	42.0	28.0
16	38.0	26.0	....	....	....	....	40.0	27.0
	38.0	24.0	....	....	....	....	44.0	28.0
	36.0	27.0	....	....	....	....	41.5	28.5
17	37.0	26.0	....	....	....	....	38.0	23.0
	40.0	26.0	....	....	....	....	44.5	29.5
	35.0	26.5	....	....	....	....	43.0	29.0
20	37.0	26.0	....	....	....	....	40.5	28.0
	42.0	27.0	....	....	....	....	44.0	29.0
	33.0	28.0	....	....	....	....	41.0	28.0
21	36.0	28.0	....	....	....	....	40.0	28.0
	37.0	25.0	....	....	....	....	40.0	27.0
	39.0	26.0	....	....	....	....	44.0	29.0
	36.0	28.0	....	....	....	....	37.0	29.5
22	42.0	28.0	....	....	....	....	40.0	25.0
	37.0	27.0	....	....	....	....	35.0	25.5
23	44.0	26.0	....	....	....	....	43.0	27.0
	36.0	27.0	....	....	....	....	40.0	28.0
24	43.0	28.0	....	....	....	....	43.5	28.5
	32.0	28.0	....	....	....	....	36.0	26.0

In nearly every case the 160° pasteurized-milk cheeses were cleaner in flavor and scored higher than the check, and in every case they scored higher than the cheeses pasteurized at 140° and 150°. The different judges scored the cheese at different ages, which will account for the wide variation of some scores. Bacterial counts made by Mr. W. H. Wright[1] show that pasteurization at 160° is more effective than at lower temperatures. This is well illustrated in Table 7.

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[1] Unpublished work by W. H. Wright, Instructor in agricultural bacteriology, University of Wisconsin.

TABLE 7.—*Bacterial content of milk pasteurized at different temperatures in the continuous-disk machine.*

Date.	Bacteria per cubic centimeter.			
	Raw milk.	Milk pasteurized at—		
		140° F.	150° F.	160° F.
1909.				
July 22	....	6,080,000	600,000	50,000
23	423,000,000	5,800,000	600,000	60,000
24	11,600,000	1,540,000	139,000	23,000

That the use of 160° for pasteurization is high enough to kill most of the bacteria in milk, so as to meet requirements such as those of the Chicago ordinance previously referred to on page 12, is shown in Table 8 by the following bacterial counts made by Mr. Alfred Larson in 1909:

TABLE 8.—*Bacterial content of milk before and after pasteurization in the continuous-disk machine at 160° F.*

Date.	Bacteria per cubic centimeter.		Decrease.
	Raw milk.	Pasteurized milk.	
1909.			*Per cent.*
Aug. 17	161,600,000	223,350	99.8
18	43,300,000	1,275,000	97.0
19	57,600,000	211,000	99.6
20	16,560,000	252,160	98.5
21	20,938,000	40,960	99.8
22	15,548,000	420,250	97.0
24	89,750,000	544,250	99.0
26	44,075,000	86,120	99.8
27	76,000,000	30,450	99.9
28	78,825,000	166,400	99.8
31	148,200,000	77,560	99.9
Sept. 1	25,836,000	9,670	99.9
2	51,650,000	52,125	99.9
14	27,150,000	29,250	99.9
16	77,650,000	341,600	99.6
17	38,900,000	136,350	99.6
18	124,700,000	159,880	99.8
19	60,280,000	287,500	99.5
21	185,000,000	477,600	99.6
22	63,500,000	263,200	99.7
23	45,525,000	142,300	99.7
28	18,376,000	202,600	98.8
29	13,660,000	31,000	99.7
30	980,000	14,580	98.5
1910.			
July 11	6,500,000	27,000	99.6
12	1,600,000	25,000	98.5
13	5,250,000	17,200	99.7
14	4,700,000	36,000	99.3
15	10,000,000	28,700	99.7
20	5,350,000	21,000	99.6
Sept. 19	2,525,000	30,000	98.8

Similar determinations were made by Miss A. C. Evans upon milk pasteurized in the continuous "flash" machine in 1910. They are shown in Table 9:

TABLE 9.—*Bacterial content of milk before and after pasteurization in the continuous "flash" machine at 160° F.*

Date.	Number of bacteria per cubic centimeter.		Killed by pasteurization.
	Raw milk.	Pasteurized milk.	
1910.			*Per cent.*
Aug. 3	7,960,000	4,700	99.96
4	4,250,000	15,300	99.65
5	9,750,000	142,000	98.45
9	1,500,000	4,850	99.68
11	6,450,000	11,250	99.83
15	2,850,000	43,600	98.47
16	1,017,500	12,725	98.75
17	38,000,000	700	99.99
18	4,500,000	6,000	99.87
19	3,750,000	5,500	99.86
24	18,150,000	13,900	99.93
25	14,000,000	6,500	99.96
30	47,300,000	16,200	99.97
Sept. 1	2,150,000	12,000	99.44
7	5,650,000	27,000	99.53
8	8,800,000	63,000	99.29
9	2,800,000	5,500	99.80
12	10,200,000	21,200	99.73
13	2,120,000	18,500	99.13
16	18,000,000	5,700	99.97
19	2,525,000	4,300	99.83
21	1,700,000	11,000	99.35
23	9,000,000	30,000	99.67
26	11,200,000	28,000	99.75

OBJECTIONS TO HIGHER TEMPERATURES THAN 160°–165° F. FOR PASTEURIZATION.

Cheese made by the new process from milk pasteurized at 160° has always a clean, mild flavor which suits practically all markets, and will please any consumer who likes a mild-flavored cheese. Those who are accustomed to and prefer very old high-flavored cheese would not be suited, but estimates by leading cheese dealers indicate that the proportion of consumers preferring the high-flavored cheese is very small. Most of the cheese sold to-day is only a few weeks old, because the dealers generally avoid long storage, preferring quick sales and immediate profits. This makes it practically impossible for most consumers to develop a taste for any but the new mild cheese sold in most markets. The steady sales of pasteurized-milk cheese during the past two years indicate that the flavor of the 160° pasteurized product is satisfactory for filling regular orders. Indeed, it is an open question whether most of the "high snappy" flavor often observed in old cheese is not due to the long-continued, slow development of those same taints and off flavors from unclean milk which we recognize as objectionable when they develop rapidly.

The use of higher temperatures than 160° for pasteurization was tried on several days, with the result that the flavor production in the cheese was practically prevented and the texture was inferior. The scores given to these cheeses are tabulated below:

TABLE 10.—*Quality of cheese from milk pasteurized at different temperatures in the continuous-disk machine.*

Date made.	Pasteurized at 160° F.		Pasteurized at 170° F.		Pasteurized at 180° F.	
	Flavor.	Texture.	Flavor.	Texture.	Flavor.	Texture.
1909.						
Oct. 12	40	29	38	27	35	15
13	40	29	39	28	35	15
14	40	28½	38	27	35	15

The scoring was done by Mr. F. W. Laabs. The 180° cheeses have no Cheddar flavor, but taste like first-class cottage cheese. They are so crumbly and short that it is impossible to draw a solid plug. They keep well, and it is possible that a good trade might be built by the sale of this product under some such name as "pressed cottage cheese." In all cases the use of 160° for pasteurizing milk gave better cheese than higher temperatures.

Three reasons have been suggested why the milk pasteurized at 180° gives flavorless cheese:

First. If bacteria are the essential cause of flavor production, it would appear likely that the necessary kinds of milk bacteria are destroyed by the high temperature of pasteurization.

Second. If milk enzyms such as galactase are the essential cause of flavor production, these enzyms are perhaps destroyed by the use of 180°.

Third. It may be that the casein or other native milk constituent which in normal cheese undergoes cleavage, forming the flavor-giving substances present in ripened cheese, is changed chemically either in composition or as to constitution by the heating to 180°, so that upon cleavage by bacteria, enzyms, acids, or other agencies it yields different cleavage products, lacking the flavor, etc., which characterize normal cheese.

In attempting to test the first of these possible explanations a variety of substances have been added as starters to milk after pasteurizing at 180° or other high temperatures in order if possible to supply the bacteria or enzym needed for normal curing and flavor production. Among the special starters so used were pure cultures of various bacteria; raw milk up to 20 per cent of the vat contents; cultures of bacteria isolated from milk and cheese capable of developing 1.6 per cent or more lactic acid in milk (described by Hastings[1]); cheese of various ages rubbed to creamy consistency with milk and added in different proportions through a hair sieve to the pasteurized milk in the vat; cultures made by adding cheese in this manner to milk and incubating overnight before adding to the cheese vat. All of these materials were added to milk which had been pasteurized at high temperatures up to 180°, and cheese was made therefrom; but in no case was it possible to get a normal flavor development in the resulting cheese.

The lack of flavor production under these circumstances, where many kinds of bacteria and starters were added to the pasteurized milk, seems to indicate that the casein, etc., in milk thus treated is incapable of cleavage into the flavor-giving substances; in other words, that the casein, etc., is changed chemically by the heat of pasteurization. There is additional evidence that such a change occurs.

EFFECT OF PASTEURIZATION ON THE PROPERTIES OF CHEESE CURD.

A series of cheese curds made from milk pasteurized at 160°, 170°, 180°, or higher temperatures show a regular gradation of certain characteristics. The higher the temperature of pasteurization the more tenaciously the curd retains moisture and the more difficult it is to expel the whey by ordinary means. This is shown in the following experiment: The milk in the receiving vat each morning was thoroughly mixed and then divided into three portions which were run through the pasteurizer at different temperatures and made up into cheese in different vats. Three-fourths per cent of starter was added to each vat and the milk and curds were handled in all respects as nearly alike as possible, the only difference being in the temperature of pasteurization. The curds in separate hoops were pressed in the same press, and the next morning moisture tests were made on each. This entire work was repeated on several days. The results are shown in Table 11.

TABLE 11.—*Moisture content of green cheese made from milk pasteurized at different temperatures in the continuous-disk pasteurizer.*

Date.	Milk pasteurized at—		
	160° F.	170° F.	180° F.
1909.	*Per cent.*	*Per cent.*	*Per cent.*
Oct. 12	38.4	42.2	46.6
13	37.0	39.9	43.5
14	39.0	40.7	45.5

[1] Hastings, E. G., Hammer, B. W., and Hoffman, C. Studies on the bacterial and leucocyte content of milk. Wisconsin Agricultural Experiment Station, Research Bulletin 6. Madison, June, 1909.

Each per cent given is the average of two closely agreeing duplicates. It is seen that in every case the higher temperatures of pasteurization cause higher moisture content in the green cheese. These curds were all cut with a three-eighths-inch knife and heated to 104° in the whey.

Even when a 180° curd was cut with one-fourth inch curd knives and a 160° curd with three-eighths inch knives, the moisture content in the former remained higher, as is shown in the following experiment:

TABLE 12.—*Moisture content of curds made from milk pasteurized at different temperatures in the continuous-disk pasteurizer and cut with knives of different sizes.*

Milk pasteurized at 160° F.				Milk pasteurized at 180° F.	
Time after cutting curd.			Cut into 3/8-inch cubes.	Cut into 3/8-inch cubes.	Cut into 1/4-inch cubes.
H.	*m.*		*Per cent.*	*Per cent.*	*Per cent.*
1	0	....	67.6	70.0	66.5
2	0	Drew whey...	60.1	63.9	61.0
2	30	....	47.2	52.4	50.6
3	30	Milled curd...	43.3	47.2	46.0
4	30	Salted curd...	42.2	45.9	44.6
4	50	Hooped curd.	41.4	45.1	43.9

Each per cent in the table is the average of two closely agreeing moisture determinations.

It is unquestionably true that pasteurized-milk curds retain moisture more tenaciously than raw-milk curds, and this effect is more marked the higher the temperature used in the pasteurization. It therefore follows that the higher the temperature used in the pasteurizer the greater will be the weight of cheese obtained from pasteurized milk. The yield per hundred pounds of milk weighed before pasteurization in each vat on three days is given in Table 13.

TABLE 13.—*Yield of cheese per hundred pounds of milk pasteurized at different temperatures.*

Date made.	Temperature of pasteurization.		
	160° F.	170° F.	180° F.
1909.	*Pounds.*	*Pounds.*	*Pounds.*
Oct. 12	12.28	13.42	15.42
13	12.10	12.97	14.53
14	11.93	12.70	14.44

It will be shown later that the yield of cheese obtained by pasteurizing at 160° is slightly greater than that obtained from raw milk, so that in this respect the effect of pasteurization is distinctly noticeable even when the lower temperature is used in the pasteurizer. Again, among the peculiarities of pasteurized-milk curds is their decreased power to coalesce or mat when on the rack or in the press. This effect is not noticeable with milk pasteurized at 160° to 165°, but is perceptible at 170° and is very marked when the milk was pasteurized at 180° or higher. The 180° curd cubes when piled on the rack pack together like raisins or figs in a box but do not coalesce or unite, and by rubbing the finger over the mass at any time the pieces can be pulled apart. The same effect is noticed when the curd is pressed in the hoop. The pieces pack together tightly but do not unite; and at any time during the curing a plug drawn with a trier will either come out in fragments or will break into pieces instantly when handled. Instead of milling such a curd, it is merely stirred or shaken apart with the hands.

These two peculiarities of pasteurized-milk curds, which can not be remedied or avoided by any other means than reducing the temperature of the pasteurization, considered together with the impossibility of developing Cheddar flavor after pasteurization at high temperatures, appear to indicate that the pasteurization produces some deep-seated change in the chemical constitution of casein.

Another peculiarity of pasteurized milk, that of coagulating with rennet only with great difficulty, need only be mentioned in this connection, because in the process of cheese making here described the addition of hydrochloric acid to the pasteurized milk entirely restores the coagulability with rennet, producing a curd in many respects superior to and easier to handle than the curd commonly obtained in the regular way from raw milk.

From what has been said it will be seen that the use of 160° to 165° for pasteurization offers many practical advantages. It is sufficiently high to check effectually the further ripening of the milk during the next few hours, while the use of 150° is not high enough for this purpose. Furthermore, 160° gives cheese of cleaner flavor than 140° or 150° (no doubt by more effectual destruction of taint-producing bacteria) or than raw milk, as shown in Table 6. It may be mentioned also that over 99 per cent of the total bacterial content of the milk is destroyed by use of 160°, as shown in Tables 8 and 9. The 160° is preferred to 170° or 180° because the cheese obtained by the use of 160° is more nearly like the best American cheese in moisture content (see Table 11) and in texture and flavor. (See Table 10.)

So far as it is possible to say at the present time, the use of 160° is sufficient to kill most probably 99 per cent of the gas and taint-forming bacteria in milk. It can not be claimed that they are all killed, because it is true that when very unclean milk is handled by this process the cheese sometimes shows slight traces of unclean flavors, though not enough to affect the market value. While gas and pin holes have often been seen during the seasons of 1909, 1910, and 1911 in cheese made by regular methods at this factory, no gas whatever was seen in any curd or cheese made during 1909 or 1911, and the gassy cheese obtained, nine days in succession, in 1910 was demonstrated to be due to the use by mistake of a gassy starter which was added to the milk after pasteurization. The fault arose at that time from the inefficient means then at hand for preparing and heating milk for propagation of the starter. An improved steam sterilizer was at once set up for this purpose, which prevented all further difficulty of this sort during the past two years.

The temperature finally selected as most completely securing the advantages and avoiding the disadvantages of pasteurization for cheese making is 160° to 165° F. In practice the pasteurizer is set running at 163° and held there as closely as possible.

THE DIFFERENT TYPES OF CONTINUOUS PASTEURIZERS USED.

Two different pasteurizers were used in this work with entire success, being apparently equally effective in producing the desired results at 160° to 165°. These were a disk machine of 2,000 pounds per hour capacity and a "flash" machine of 1,200 pounds capacity per hour. (See Pls. II and III.) The choice between these two types of pasteurizing machines for use in this process appears to depend upon their relative cost and ease of operation and cleaning, rather than upon any difference in effectiveness. They were used alternately on successive days for several weeks, and on three days, September 1, 12, and 19, 1910, the milk was divided, one-half being run through each. The cheese was first class in each case and showed no differences that could be traced to the use of different machines.

THE ACIDULATION PROCESS.

THE STANDARD ACIDITY OF MILK FOR CHEESE MAKING.

Milk as it flows from the pasteurizer varies daily in acidity and is lacking in bacteria of the lactic-acid type, needed to aid in cheese curing. By the addition of sufficient hydrochloric acid to raise the acidity of the milk to 0.25 per cent (as lactic acid) after pasteurizing, and of three-fourths per cent of a first-class starter, the pasteurized milk is brought daily into standard condition both as to acidity and bacterial content for cheese-making purposes. The reasons for adding acid and starter as specified will now be given in detail.

The standard acidity is 0.25 per cent, and the acidity of pasteurized milk is raised to this figure rather than to 0.20 or 0.30 per cent for the following reasons:

First. In regular cheese making the acidity of whey when drawn is, on the average, about 0.17 per cent, corresponding to an acidity of milk of about 0.25 per cent. Anyone can test the correctness of this statement by transferring a pint of milk from a cheese vat, just before adding rennet, to a small tin pail, keeping the milk sample at the same temperature as the vat and titrating the milk in the pail as well as whey from the vat at intervals. When the whey reaches 0.17 per cent the milk reaches nearly 0.25 per cent.

The control of acidity at the instant the whey is drawn is commonly regarded as most important in regular cheese making. With milk pasteurized at 160° there is little or no increase of acidity (usually about 0.01 per cent) in whey, before the whey is drawn. The acidity of milk is adjusted to 0.25 per cent in this process after pasteurizing in order to parallel ordinary working conditions at the time of drawing the whey.

Second. Mixed milk in the factory cheese vat is commonly at 0.16 to 0.18 per cent acidity when received, although often at 0.19 to 0.21 per cent. It should never be over 0.23 per cent acidity. It is found that an addition of hydrochloric acid equal to at least 0.02 per cent of lactic acid is required to restore the coagulability with rennet to such milk after pasteurization, but the daily addition of only 0.02 per cent of acid would leave the milk of varying acidity, which is objectionable. If 0.20 per cent were adopted as the standard acidity, after adding 0.02 per cent in the form of hydrochloric acid, this rule would exclude from use all milk having a higher acidity than 0.18 per cent when received, which it is not desirable to do. Only rarely is a vat full of milk at 0.23 per cent acidity received at any factory, but even such milk can be handled in the routine manner at the standard acidity of 0.25 per cent by adding the required 0.02 per cent of hydrochloric acid after pasteurization.

It might be stated as a matter of record, not as a precedent for factory practice, that vats of milk of 0.24 to 0.28 per cent acidity when received have been successfully made up into good cheese without varying the process in any particular, excepting that only enough acid is added after pasteurization to raise the acidity 0.01 per cent, which is sufficient to restore the rennet coagulation to such ripe milk. The only apparent limit of acidity for milk to be handled by this process is that the milk should not, of course, be sour enough to curdle in the pasteurizer, and this limit is reached at or about 0.30 per cent.

However, it should be recognized by everyone that milk that has reached 0.30 per cent or even 0.25 per cent acidity before it gets to the cheese factory must have received very poor care and attention on the farm and must be entirely unfit for cheese making from a sanitary point of view.

COMPARISON OF DIFFERENT KINDS OF ACIDS FOR USE IN CHEESE MAKING.

Of the more common acids—sulphuric, hydrochloric, and phosphoric—the first is the least convenient to handle, especially in a cheese factory, because of the great amount of heat liberated when it is diluted, and the impossibility of diluting it in the carboy in which it is received. Hydrochloric acid is much better in this respect as it can be readily diluted with an equal volume of water by pouring the water into the acid with no danger and very little heat evolution. Thus diluted it fumes very little, if at all, and can be readily and accurately standardized by titration with normal caustic soda and phenolphthalein indicator. Phosphoric acid can be purchased in carboys of about 50 per cent strength, requires no dilution in the carboy, and liberates little or no heat when diluted.

The choice between hydrochloric acid and acid made from phosphorus is greatly in favor of the former because of the high cost of the latter. Recently, however, phosphoric acid made from bone ash or bone black has been put on the market in this country, containing about 45 per cent free phosphoric acid and less than 1 per cent each of hydrochloric acid, sulphuric acid, and phosphates of iron and alumina, this product being offered at 6 cents a pound in paraffined barrels. The price of this acid is very nearly the same as that of chemically pure hydrochloric acid for equal neutralizing power.

Chemically pure hydrochloric acid is and has been for years a standard article of manufacture, whose purity is tested daily by use in hundreds of laboratories. On the other hand, the manufacture of phosphoric acid from bone ash in a form free from objectionable impurities has been accomplished only very recently.

A number of cheeses were made with phosphoric acid, but these showed no advantage over those made with hydrochloric acid; indeed they seemed to have a slight peculiarity of flavor, as a rule, after curing. Most of the cheeses made from pasteurized milk have so far been made with hydrochloric acid, and the use of this acid is described and recommended in the present bulletin.

The selection of hydrochloric acid was made because it is cheap and more easily obtained than any other chemically pure acid, and being a natural constituent of gastric juice in the human stomach, no objection could be raised on sanitary or other grounds against its use in this process.

THE PROPORTION OF HYDROCHLORIC ACID REQUIRED DAILY.

It is necessary to determine first what the acidity of each vat of the mixed milk is, in order after pasteurizing to add the requisite quantity of hydrochloric acid to bring the acidity up to 0.25 per cent. Where only one vat of milk is to be pasteurized and only one workman is employed it is probably better to weigh in all the milk then stir the vat well and take out a half cupful of milk for the acid test.

Where two men are employed and it is desired to start the pasteurizer running as early as possible (before the receiving vat is full), the intake man should take from each weigh can of milk a sampling tube full, mixing these samples in a pint jar. The acidity of this mixed sample will then be the same as the average acidity of all the milk run into the vat. As soon as one vat full of milk (say 5,000 pounds) has been run from the weigh can into the receiving vat, the pint jar containing the sample for the acid test is handed from the intake to the man running the pasteurizer, together with the total weight of milk run into that vat. The pasteurizer was started when perhaps only half of this milk had been received, but the receiving vat is still about half full, and after making the acid test on the sample the operator can tell exactly how much more hydrochloric acid must be added, while pasteurizing the remaining milk in order to bring the acidity of the whole vat up to the right point, or 0.25 per cent.

TESTING MILK FOR ACIDITY.

In determining the acidity of milk, measure a 17.6 cubic centimeter pipette full of milk sample into a white china cup, which should be shallow and wide rather than narrow and deep. Add two drops of phenolphthalein indicator and while shaking or stirring the milk in the cup run in tenth-normal alkali (Manns's solution) from a burette, rapidly at first, and later by single drops, until the faint pink color produced by the last drop does not disappear on thorough mixing. The volume of tenth-normal alkali used is read from the burette, and this volume divided by 20, which can be done mentally, gives the exact acidity of the milk in per cent of lactic acid by weight. For example, if the volume of alkali solution used was 3.2 cubic centimeters the acidity is 3.2 divided by 20, which equals 0.16 per cent. Subtracting the acidity of the raw milk from 0.25 per cent shows how much the acidity of the milk is to be raised with hydrochloric acid after pasteurizing. For example subtracting 0.16 per cent from 0.25 per cent leaves 0.09 per cent, which shows that the acidity is to be increased 0.09 per cent with hydrochloric acid.

The outfit needed for testing milk is shown in Plate I. It consists of:

1. A burette with rubber tip and pinchcock; capacity 25 c. c., with $\frac{1}{10}$ c. c. graduations.
2. A 17.6 c. c. pipette as used for the Babcock test.
3. A white china teacup, which is best if shallow and wide and with flat bottom.
4. A support for the burette, which may be an iron stand and clamp, or a wooden strip with a hole in it, fastened to a window casing, as shown at the left in Plate I.

5. A rubber-stoppered bottle of Manns's solution (tenth-normal alkali) which may be purchased at $1 per gallon of dealers in dairy supplies, or may be made by diluting the normal alkali solution, which must be purchased as it is required in this process as described on page 36.

6. A 2-ounce or 4-ounce bottle of phenolphthalein indicator solution.

7. The additional outfit required for use in this process of cheese-making is also shown in the figure. It consists of 1 gallon of normal alkali (ten times as strong as Manns's neutralizer), a 50 cubic centimeter measuring flask, a 500 cubic centimeter measuring cylinder, and a 2 cubic centimeter pipette, which should be accurately made. A gallon of normal caustic alkali contains about 5 ounces of caustic soda, worth about 15 cents, and should cost the cheese maker no more than a gallon of tenth-normal solution—that is, about $1.

PRESERVING THE TENTH-NORMAL SOLUTION.

Instead of using the large bottle of tenth-normal solution to fill the burette with, it is much better to get a smaller bottle, holding 6 or 8 ounces, also provided with a rubber stopper, and to fill this smaller bottle occasionally from the larger bottle, which is then put away, tightly stoppered, in a safe place. The small bottle is kept near the burette and used daily in filling it, and the large bottle is thus protected from unnecessary exposure, loss of strength, and from danger of spilling. The use of two bottles in this manner has proven most satisfactory in this laboratory and dairy school during the past four years. It is recommended[1] as a means of avoiding loss of strength through exposure to the air, which has heretofore been the greatest difficulty to overcome in the use of Manns's test in the cheese factory.

DILUTING NORMAL ALKALI TO TENTH-NORMAL.

One may prepare tenth-normal alkali by diluting the normal alkali as follows: Pour into a 500 cubic centimeter graduated cylinder exactly 50 cubic centimeters of the normal solution measured in the 50 cubic centimeter flask. Add at once 450 cubic centimeters of pure water, either rain water or condensed steam. Pour the mixture into a clean glass bottle, mix by shaking, and keep stoppered with a rubber stopper to avoid loss of strength by exposure to air. If the mixture is muddy or turbid, the water used in diluting was not pure. A slight turbidity may be neglected.

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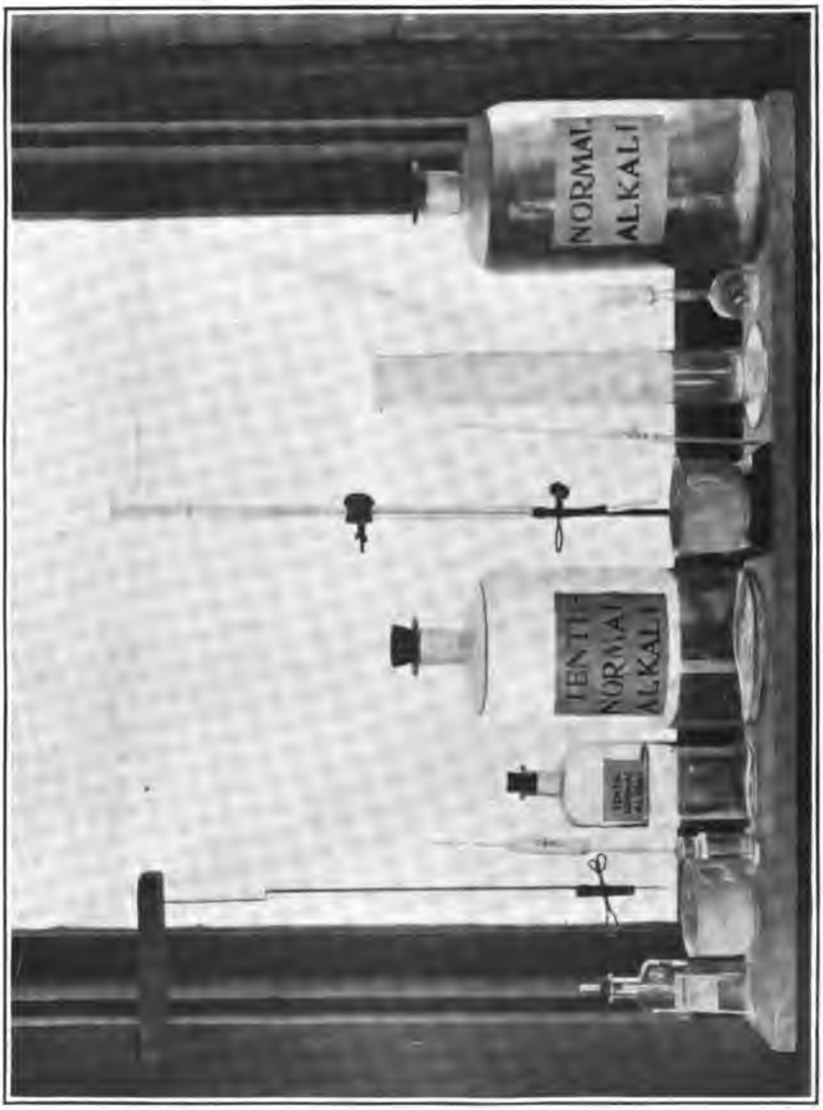
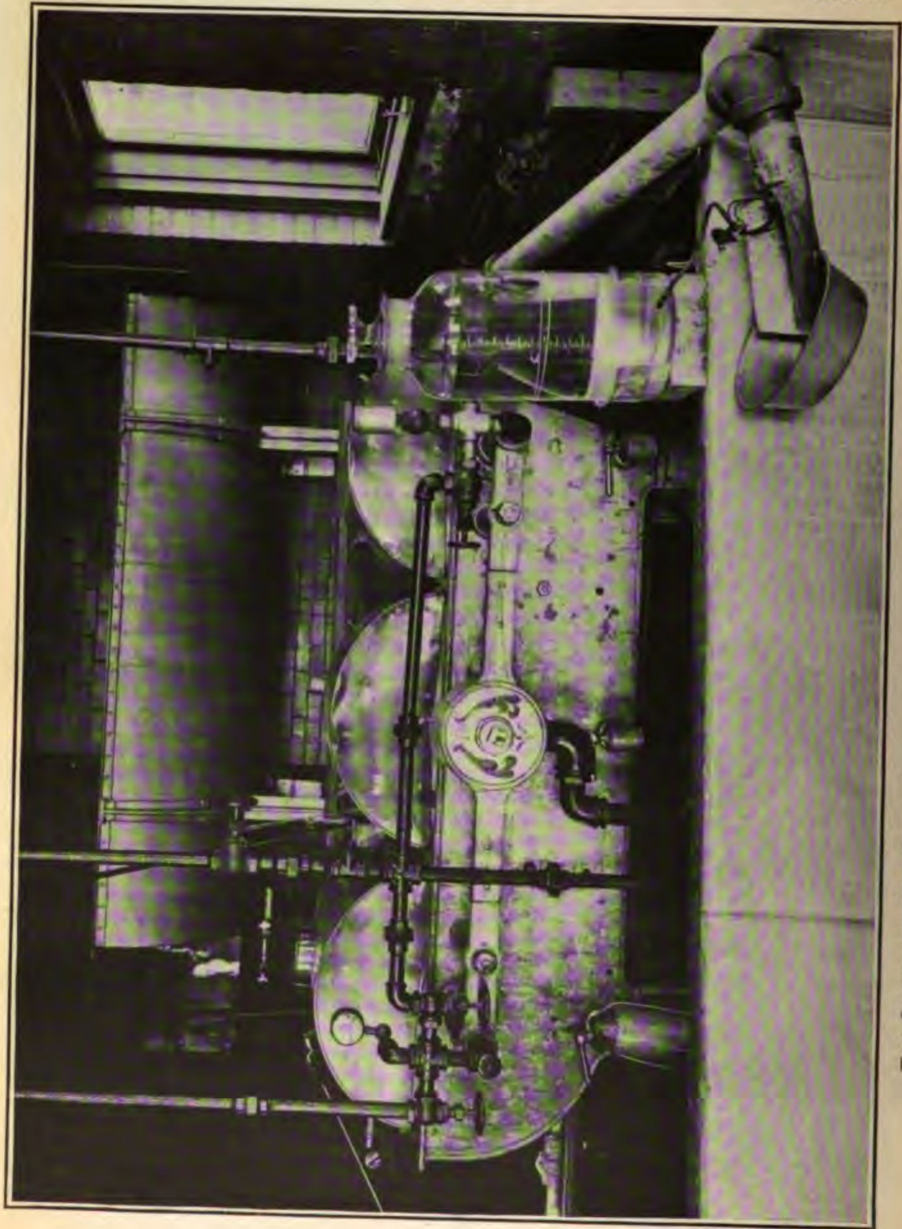
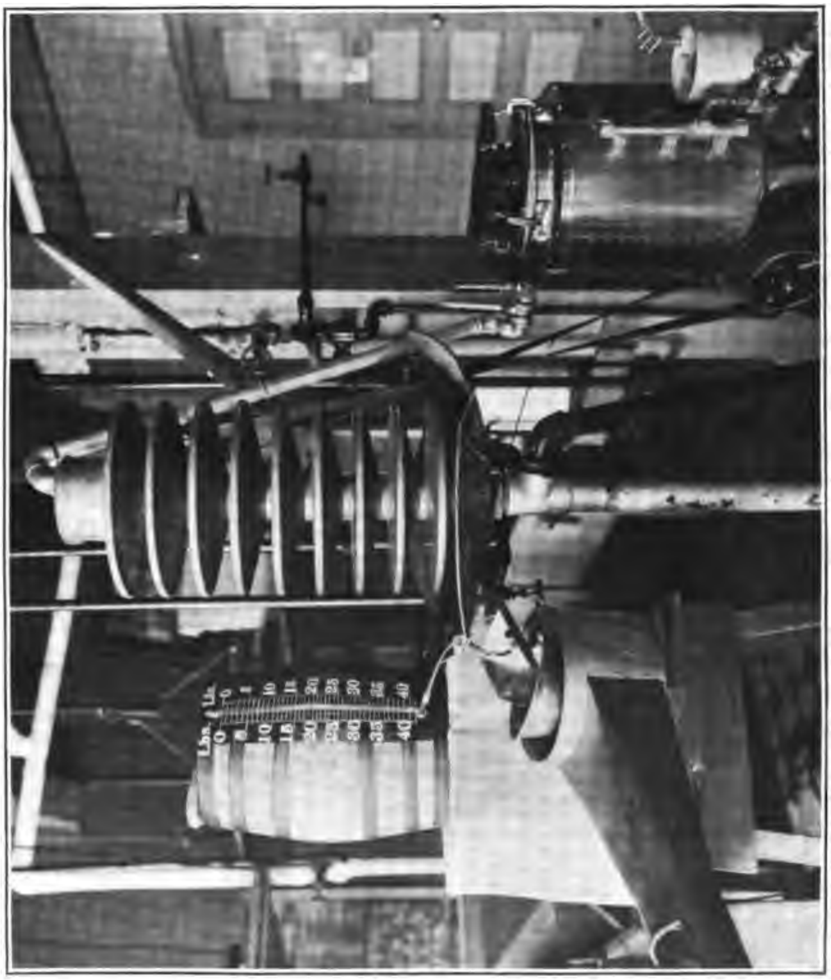
[1] Sammis, J. L. The preservation of Mann's alkaline solution in cheese factories. Hoard's Dairyman, vol. 40, No. 41, p. 1200. Fort Atkinson, Wis., Nov. 12, 1909.



OUTFIT USED FOR TESTING MILK FOR ACIDITY (MANN'S ACID TEST) AND IN TESTING STRENGTH OF HYDROCHLORIC ACID USED IN CHEESE MAKING.



THE CONTINUOUS DISK PASTEURIZER AND APPARATUS USED IN ACIDULATING PASTEURIZED MILK.



THE CONTINUOUS "FLASH" PASTEURIZER AND APPARATUS USED IN ACIDULATING PASTEURIZED MILK.

ADDING ACID TO MILK AFTER PASTEURIZATION.

For this purpose the acid of normal strength is placed in an acid-proof container on a shelf near the outlet of the cooler. A glass bottle or a paraffined wooden cask can be used, as shown in Plate III. The container has a small opening on one side near the bottom, through which the acid is drawn by a rubber tube of one-eighth or one-quarter inch internal diameter closed by a screw pinchcock. On the outside wall of the container, beginning at the top, a scale is engraved or otherwise permanently attached, with graduations showing pounds, halves, and quarters of acid delivered. If the container is opaque, a glass level-tube placed outside near the scale shows the acid level within at any time. The capacity of the acid container should be about 10 gallons for use with a 7,000-pound vat of milk. In addition, a two-quart tin pan is connected by means of a short piece of conductor to the cooler outlet. The milk from the cooler and acid from the container are thoroughly mixed in the conductor and mixing pan, from which the acidulated milk overflows and runs into the cheese vat.

In order to avoid coagulation of milk with acid, the acid is added from a jet so as to strike the cooled milk while the latter in a thin stream is moving rapidly down the short, steeply inclined piece of open-conductor pipe. The mixture then enters the mixing pan and its direction is abruptly changed twice, thus securing thorough mixing of milk and acid before it flows over the edge of the pan into the cheese vat.

In using this acidulator there is never any danger of coagulation if the operator remembers always to shut off the acid before the milk flow stops. It has been repeatedly shown that 2 pounds of acid, or twice as much as commonly required, can be safely added in this manner to 100 pounds of milk at 60° to 80° F. without causing coagulation. If any small particles of curd are formed, they rise to the surface of the milk when quiet in the vat and can be plainly seen. They can then be taken up with a hair sieve and rubbed through the sieve into the milk without causing loss of yield. In practice, the acidity of the vat of milk, when all in and stirred, always comes between 0.24 and 0.26 when attempting to make it 0.25 per cent, and this degree of accuracy is entirely satisfactory.

CALCULATING THE AMOUNT OF ACID TO BE ADDED.

To calculate how many pounds of normal hydrochloric acid are required by any vat of milk after pasteurizing, it should be remembered that 1 pound of the acid added to 100 pounds of milk will raise its acidity just nine hundredths (0.09) per cent. From this it is easy to see that for 2,500 pounds of milk, of 0.16 per cent acidity, just 25 pounds of normal strength acid will be required, and for 3,050 pounds of milk 30.5 pounds of acid will be needed, etc. If the milk showed an acidity of 0.21 per cent when raw, then subtract 0.21 from 0.25, which leaves 0.04 per cent. In this case, since the milk is riper to start with, less acid will need to be added; only four-ninths of a pound of acid for each 100 pounds of milk will be necessary to bring the acidity up from 0.21 to 0.25 per cent. In any case the weight in pounds of acid required is equal to $\frac{0.25 - \text{acidity of raw milk}}{.09} \times \frac{\text{weight of milk}}{100},$ or $0.25 - \text{acidity of raw milk} \times \frac{\text{weight of milk}}{9.0}.$ Stated in words, the rule is, divide the weight of milk by 9 and multiply by 0.25 minus the acidity of the raw milk.

The following table shows the amount, in pounds, of normal acid required to be added for each 100 pounds of milk when the acidity of the latter before pasteurizing is 0.15, and for each one-hundredth increase up to 0.27:

TABLE 14.—*Weight of normal acid required to be added for each 100 pounds of milk.*

Acidity of milk when pasteurized.	Weight of normal acid added to 100 pounds of milk.	Acidity of milk after the addition of acid.
Per cent.	*Pounds.*	*Per cent.*
0.15	1.11	0.25
.16	1.00	.25
.17	.88	.25
.18	.77	.25
.19	.66	.25
.20	.55	.25
.21	.44	.25
.22	.33	.25
.23	.22	.25
.24	.11	.25
.25	.11	.26
.26	.11	.27
.27	.11	.28

Where milk appears to be of, say, 0.175 per cent acidity when received, it is treated as if it were at 0.17 per cent, dropping the 0.005 out of the calculation.

The following table, conveniently posted, may aid in calculating the weight of acid required for any weight of milk at any acidity:

TABLE 15.—*Weight of normal hydrochloric acid required for stated quantities of milk at stated acidities.*

Weight of milk.	Hydrochloric acid required when acidity is—										
	0.27 to 0.24.	0.23.	0.22.	0.21.	0.20.	0.19.	0.18.	0.17.	0.16.	0.15.	0.14.
Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
10,000	11.1	22.2	33.3	44.4	55.5	66.6	77.7	88.8	100.0	111.1	122.0
9,000	10.0	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0	110.0
8,000	8.9	17.8	26.7	35.6	44.4	53.3	62.2	71.1	80.0	88.9	97.8
7,000	7.8	15.5	23.3	31.1	38.9	46.7	54.4	62.2	70.0	77.8	85.6
6,000	6.7	13.3	20.0	26.7	33.3	40.0	46.7	53.3	60.0	66.7	73.3
5,000	5.6	11.1	16.7	22.2	27.8	33.3	38.9	44.4	50.0	55.5	61.1
4,000	4.4	8.9	13.3	17.8	22.2	26.7	31.1	35.5	40.0	44.4	48.9
3,000	3.3	6.7	10.0	13.3	16.7	20.0	23.3	26.6	30.0	33.3	36.7
2,000	2.2	4.4	6.7	8.9	11.0	13.3	15.6	17.8	20.0	22.2	24.4
1,000	1.1	2.2	3.3	4.4	5.5	6.7	7.8	8.9	10.0	11.1	12.2
900	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0
800	.9	1.8	2.7	3.6	4.4	5.3	6.2	7.1	8.0	8.9	9.8
700	.8	1.6	2.3	3.1	3.9	4.7	5.4	6.2	7.0	7.8	8.6
600	.7	1.3	2.0	2.7	3.3	4.0	4.7	5.3	6.0	6.7	7.3
500	.6	1.1	1.7	2.2	2.8	3.3	3.9	4.4	5.0	5.6	6.1
400	.5	.9	1.3	1.8	2.2	2.7	3.1	3.6	4.0	4.4	4.9
300	.4	.7	1.0	1.3	1.7	2.0	2.3	2.7	3.0	3.3	3.7
200	.2	.4	.7	.9	1.1	1.3	1.6	1.8	2.0	2.2	2.4
100	.1	.2	.3	.4	.6	.7	.8	.9	1.0	1.1	1.2
75	.08	.17	.25	.34	.42	.50	.60	.67	.75	.83	.92
50	.06	.11	.17	.22	.28	.33	.39	.44	.50	.56	.61
25	.03	.06	.09	.11	.14	.16	.19	.22	.25	.28	.31

To find how much normal hydrochloric acid will be needed to raise 6,754 pounds, for example, of milk of 0.17 per cent acidity to 0.25 per cent acidity, take from the table the figure given under 0.17, opposite 6,000, which is 53.3; add to this the figure opposite 700, which is 6.2; then add the figure opposite 50, which is 0.44; the total gives the number of pounds of acid required, namely, 59.9 pounds.

PREPARATION OF NORMAL HYDROCHLORIC ACID IN THE CHEESE FACTORY.

Chemically pure hydrochloric-acid solution, as purchased in carboys containing about 120 pounds each, contains about 40 per cent by weight of hydrochloric acid and 60 per cent of water, and costs about 7 cents a pound. Its strength varies somewhat, and it must be diluted with water before it can be added to milk in this process. The preparation of normal-strength acid used in cheesemaking is carried on at the cheese factory in two steps, as follows:

First step.—Remove the wooden cap from the top of a fresh carboy of acid and loosen the glass plug in the neck by tapping it on different sides very gently with a piece of wood (not metal) until it can be drawn out readily with the hand. Set an empty carboy alongside the newly opened carboy. Fill both limbs of a glass siphon with water, removing all air bubbles, and insert the two limbs into the carboys at once, as shown in Plate IV. When the siphon is in place, as shown in the lower figure, the acid will flow from the full carboy into the other until in about half an hour each is practically half full. Now fill up each carboy nearly to the neck with water, leaving space enough beneath the neck to permit mixing the contents readily by shaking. Tip each carboy up on one edge and rock vigorously for about five minutes with the stopper out to induce thorough mixing. The liquid gets slightly warmer on mixing, and it is stoppered and left to stand overnight to cool and is then called "dilute" acid.

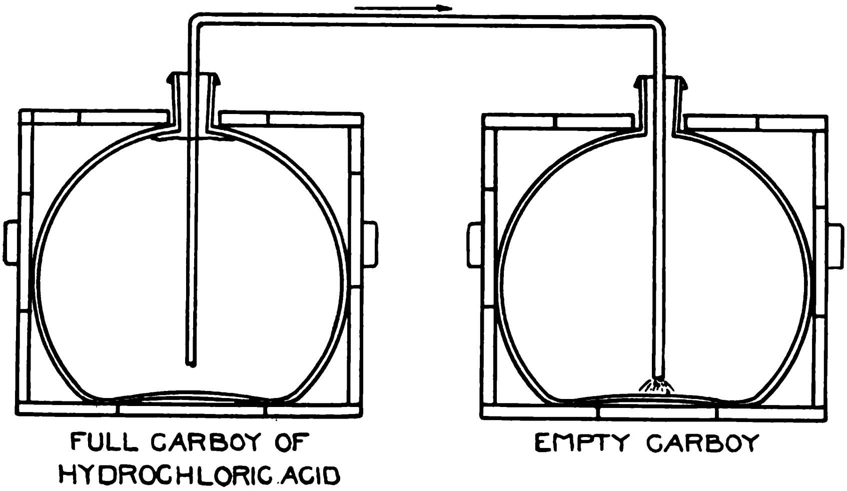
To determine how much further each carboy of dilute acid requires to be diluted with water to make it exactly "normal" in strength, set up the burette used in Manns's test, but fill it with normal alkali solution, which is 10 times as strong as that used in testing milk. Using a 2 cubic centimeter pipette, transfer exactly 2 cubic centimeters of the dilute acid from the carboy to the porcelain cup containing a little pure water, letting the pipette drain into the cup half a minute by the watch and blowing out the last drop of acid from the tip into the cup. Now add one or two drops of indicator and after reading the level of alkali in the burette, draw out the alkali from the burette, precisely as in testing milk, rapidly at first, later by single drops while shaking the cup in a circle until the last drop added produces a distinctly pink color which remains throughout the entire liquid after thorough mixing. Read and record the volume of alkali solution used. Rinse out the cup, fill up the burette, shake up the acid in the carboy for a minute and test another 2 cubic centimeters of the acid for the sake of accuracy.

If the contents of the carboy were thoroughly mixed at first, the two titrations will agree closely, not differing by more than 0.20 cubic centimeter. If they do not agree, the carboy contents were probably not well mixed at first, and should be given another very thorough shaking for five minutes, after which the titrations are repeated. Once thoroughly mixed the acid and water remain mixed, and never need to be shaken again.

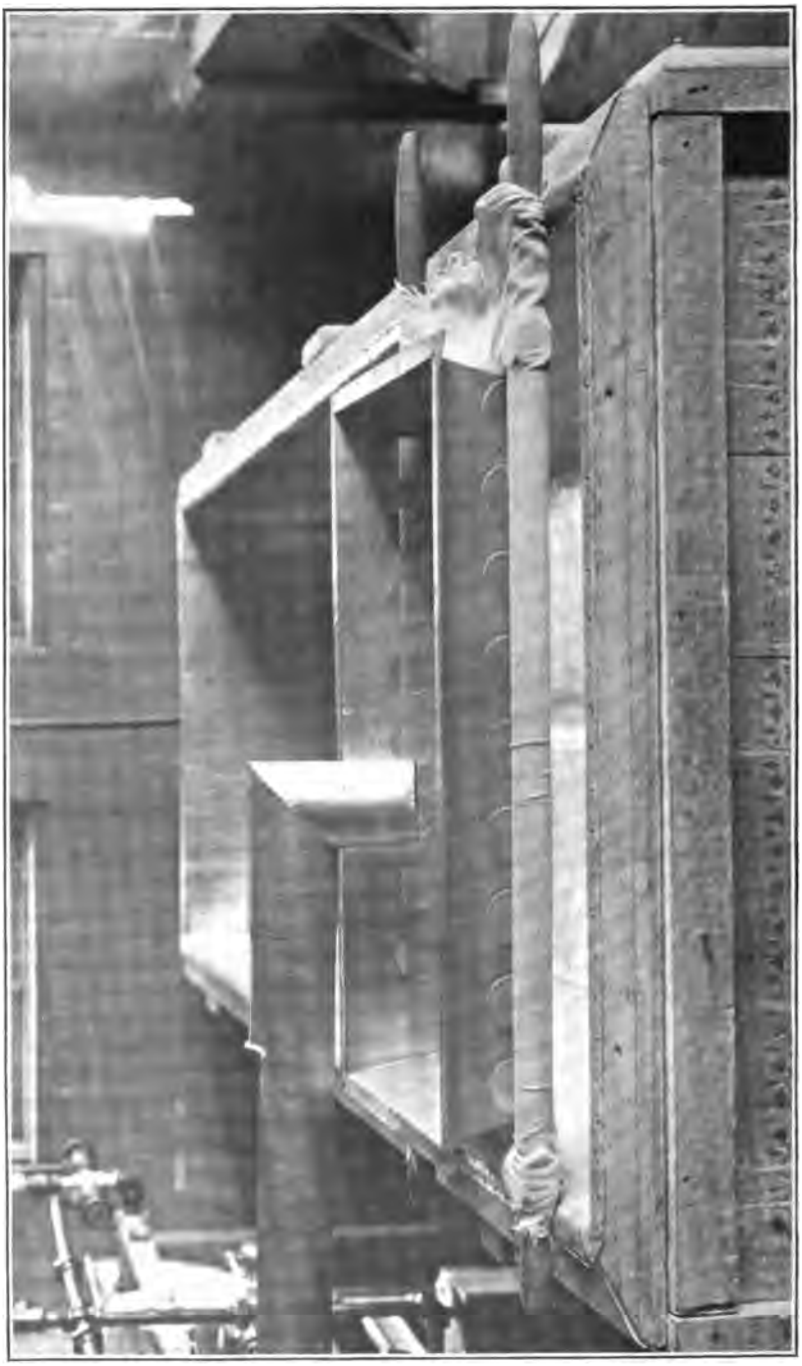
Suppose that in the two tests the 2 cubic centimeters of acid required 11 and 11.2 cubic centimeters of normal alkali to produce the pink color, the average being 11.1 cubic centimeters. Divide the volume of alkali by 2—the volume of acid used—which gives in this case $\frac{11.1}{2} = 5.55$. This means that the acid is 5.55 times as strong as it should be for normal acid, and that it must be diluted to 5.55 times its volume with water to make it exactly normal in strength.

The work described above is performed once on each carboy of dilute acid before using it for cheesemaking, and the object is to get the figure (5.55 in this case) which shows how much too strong the acid is, and how much it must be diluted to make it normal in strength.

Second step.—The second step consists in diluting up, each day, as much of the acid as will be needed for the milk on that day. This


FULL CARBOY OF HYDROCHLORIC ACID
EMPTY CARBOY

TRANSFERRING ACID FROM FULL TO EMPTY CARBOY BY MEANS OF SIPHON.



VAT STRAINER FOR STRAINING MILK INTO RECEIVING VAT.

is performed as follows: Having determined that the dilute acid is 5.55 times stronger than normal, the acid is further diluted for use each day, adding 1 volume of acid to 4.55 volumes of water, thus making the total volume 5.55 times as great as the acid used.

To do this, measure out any convenient volume (say 500 cubic centimeters for about 2,500 pounds of milk) of the acid in a glass cylinder and add it to 4.55 times its volume of water (in this case $500 \times 4.55 = 2{,}275$ cubic centimeters water). The acid should always be measured, but if more convenient the water can be weighed in pounds if it is remembered that 453 cubic centimeters of water weigh 1 pound. In this case $\frac{2{,}275}{453} = 5.02$ pounds of water needed.

The acid and water can be mixed in the acidulator or in a wooden pail, or in a bright tin pail, if the water is put in first and the acid added later. After the proper amounts of acid and water have been poured into the acidulator, they should be thoroughly mixed at once by stirring with a wooden paddle, and once thoroughly mixed the normal acid is always ready for use. Of course the acid should not be handled in galvanized iron or aluminum vessels, as it will rust them. The undiluted acid will also discolor tinware and should be measured in the glass cylinder, as directed. The "dilute" acid is drawn from the carboy into a gallon glass bottle through a glass siphon, which is first filled with water. The water used in the siphon is so small in volume—about 1 per cent of a gallon—that it does not noticeably affect the strength of the acid.

There is nothing difficult about the preparation of normal-strength hydrochloric acid for use in cheese making, and anyone who knows how to titrate milk for acidity can learn to do this also. To test the correctness of the work when completed, transfer two cubic centimeters of the acid with a pipette from the acidulator to the porcelain cup, and titrate it with the normal alkali in the burette. The volume of alkali required should be between 1.9 cubic centimeters and 2.1 cubic centimeters, or, better, exactly equal to the volume of acid used.

The degree of accuracy required in this whole process is very easily attained, as quite satisfactory results will be obtained in acidulating milk if the normal acid used is anywhere between 0.95 and 1.05 normal.

GENERAL DIRECTIONS FOR PASTEURIZING AND ACIDULATING MILK.

The method described is well adapted for use in a large factory. At a factory handling two to three large vats of milk daily two men should be employed. The inspection and weighing of milk at the intake is performed by one man while the other makes the determitions of acidity and runs the pasteurizer. After the milk is all in and pasteurized the two men work together, heating up the vats, adding the starter, color, and rennet to the vats at least 10 or 15 minutes apart. They cut the curds in the same order, each 25 minutes after the rennet has been added, and start the agitators in each curd as soon as cut. The vats are heated up and the whey is drawn from the vats in the same order, both men working together in putting the curds on the rack, finishing each vat of curd in time to handle the next.

If more than three vats are handled in one factory, additional help will be needed, especially for bandaging hoops, turning cheese, and other labor.

Where only one vat of milk is handled daily, the milk is run first into the receiving vat, from which it flows into the pasteurizer, through the cooler, and into the cheese vat. If two vats of milk are handled daily, the first milk received may be run into one cheese vat, from which it is pasteurized into the other cheese vat, while the milk received later is run into the steel receiving vat, from which it is pasteurized into the second cheese vat.

If three or more vats of milk are handled daily, the receiving vat and the first cheese vat are filled alternately with milk from the intake, and alternately emptied through the pasteurizer into the other cheese vats. It is only necessary to see to it that the last vat filled from the intake shall be the receiving vat in order that this last milk may be run into one of the cheese vats after pasteurization. One receiving vat is needed in addition to the necessary cheese vats wherever this process is used.

MAKING READY TO PASTEURIZE.

Since pasteurization is essentially a cleaning process, care should be taken to keep the make room, the vats, machinery, etc., and everything with which the pasteurized milk comes in contact as clean as possible.

Although milk flows intermittently from the weigh cans, it is desirable that the pasteurizer, once started, shall run continuously, with a steady milk supply, and for this purpose a receiving vat is provided. The milk should be run into the receiving vat through a strainer which will remove all flies, straw, etc., and which can not by accident fail to work properly. Such a strainer is shown in Plate V. It is set up by slipping a piece of seamless cheese bandage over the wooden frame of the vat strainer and placing the metal part on top. The metal part collects all large pieces of dirt and prevents the milk from splashing over the side. The two thicknesses of cheesecloth effectually remove finer particles of dirt. This arrangement has been used in this series of experiments for about two years and is heartily recommended. Of course the cloth should be scalded daily.

The weigh can, conductors, receiving vat, and pasteurizer should be washed daily, immediately after use, and again rinsed with clear hot water before use, if necessary. The pasteurizer and cooler and the connecting pipes should be washed thoroughly daily. Just before starting the pasteurizer each morning the operator should rinse out the cheese vat and steam it by running steam into the jacket. The pasteurizer and delivery pipes, especially those parts which are in contact with the cooled pasteurized milk, should be also scalded or steamed. This can be done by running a couple of pails of hot water into the heating compartment, heating it there to 180° or higher, and running it over the cooler without having any cold water inside the cooler.

Where only one vat of milk is being pasteurized, the acidulator may be set on the edge of the vat, but to avoid moving it, when several vats of milk are handled daily, the acidulator should be set near the pasteurizer and the acidulated milk run into the different vats through a movable conductor, as shown in Plate III.

STARTING AND STOPPING THE PASTEURIZER.

When milk enough has been received to insure a continuous supply for the pasteurizer, the latter may be started.

First, see that everything is in place and that the pump supplying water for cooling is running. Set the pasteurizer in motion, turn on a little steam, and run enough milk into the heating compartment nearly to fill it so as to register its temperature on the naked glass bulb of the thermometer placed near the exit to the cooler. Do not allow any milk at all to run into the cooler. If any does by accident, draw it out and scald the cooler with a pail of hot water.

Open the steam valve to the full running capacity. When the thermometer in the milk registers about 155° start the milk supply again and adjust so that the thermometer stands at 162° at the exit from the heater. Use care to see that no milk at all is allowed to run to the cooler at a temperature below 160°. If any irregularity occurs in starting, it is much better that the first milk should be heated higher than 160°, even up to 180°, rather than that any portion should pass over into the cheese vat without reaching 160°. It will do no harm at all if for a few minutes at first milk at 170° or 180° passes over into the cooler, because this milk will at least be thoroughly pasteurized, but if milk at 140°, or any temperature below 160°, passes over it may carry over harmful bacteria which may injure the entire vat of cheese. A file mark on the steam-valve handle is a great help in quickly adjusting the steam supply to the right point.

Once adjusted, and with steady milk and steam supply, the pasteurizing temperature remains nearly constant and requires only momentary inspection every few minutes. No doubt an automatic temperature-controlling device could be used to advantage here.

Although the thermometer now supplied with some forms of pasteurizers is metal jacketed to prevent breakage, yet in all the experiments here reported this metal-cased thermometer was found to register more slowly than a naked glass-bulbed thermometer, set in a rubber stopper. The latter kind has been in use two years without breaking and is therefore preferred.

In stopping the pasteurizer for any reason, the operator should remember to stop the acidulator first, then the milk supply, and last of all the steam. If the stoppage is for long, as at the end of the day's run, the hot milk in the heating compartment is drawn out in a pail (its temperature should be 160° or above) and added to the vat. The milk in the cooler is also drained and rinsed, if desired, into the vat.

The water supply for cooling must be ample so that a thermometer placed in the milk flowing from the cooler is not above 85° at any time, and preferably at 80° or lower, since the milk in the vat can easily be heated to 85°–86° for setting with rennet, but can not so well be set, or easily cooled, if above 86°.

STARTING AND STOPPING THE ACIDULATOR.

As soon as the pasteurizer has been started and regulated the pinchcock at the acidulator is opened, allowing one or more small streams of hydrochloric acid to run into the milk. The height of the liquid in the acidulator should be marked on the glass scale with a pencil or string, when starting, and another mark placed lower down on the scale to show how much acid is to be drawn out for that vat of milk. By this means the operator can see from any part of the room when the acidulator is ready to be stopped. Always stop the acidulator before stopping the milk.

THE USE OF BACTERIAL STARTER IN THE NEW PROCESS.

THE REASON FOR ADDING STARTER IN MAKING PASTEURIZED-MILK CHEESE.

The addition of the required amount of hydrochloric acid to milk raises its acidity at once to 0.25 per cent, but does not cause any further increase of acidity at any time. Of the acid thus added, only about one-fortieth remains in the curd, the rest escaping in the whey. No chemical method has been found for increasing the acidity of a curd on the rack, so that if acid plays any important part in the cheese-curing process, it will be necessary to add bacteria to the milk in order to develop the necessary acid in the curd and cheese. A number of experiments were performed in which the milk supply was divided and made up in different vats, using different proportions of starter. The cheese was finally scored by Mr. J. W. Moore with the following results:

Table 16.—*Quality of cheese made from pasteurized milk with varying amounts of starter added.*

Date. made.	Cheese No.[1]	Proportion of starter.	Temperature of pasteurization.	Score.	
				Flavor.	Texture.
1908.		*Per cent.*	°*F.*		
Aug. 17	1076c	....	....	40.50	27.00
	1079	0.25	157	40.50	27.25
	1081	.50	157	41.25	27.25
	1083	.75	157	42.50	28.00
18	1085c	....	....	41.00	27.25
	1087	.25	157	41.75	27.75
	1889	.50	157	41.00	27.25
	1091	.75	157	40.25	27.00
19	1093c	....	....	40.50	27.00
	1095	.25	157	41.25	27.00
	1097	.50	157	42.50	27.75
	1099	.75	157	42.75	28.00
20	1101c	....	....	41.25	27.00
	1103	.25	157	42.50	28.25
	1105	.75	157	42.25	27.75
21	1109c	....	....	40.75	27.00
	1111	.75	157	42.25	27.25
	1113	1.00	157	42.50	27.25
	1115	1.25	157	42.50	27.75
22	1117c	....	....	39.50	27.25
	1119	.75	157	42.25	27.00
	1121	1.00	157	41.75	27.25
	1123	1.25	157	42.25	27.00
31	1157c	....	....	41.00	27.00
	1159	None.	162	41.00	27.00
	1161	.3	162	42.50	28.00
	1163	.6	162	42.50	28.00
Sept 1	1165c	....	....	39.00	28.50
	1167	None.	162	40.50	26.00
	1169	.3	162	42.00	27.50
	1170	.6	162	42.50	28.00
2	1173c	....	....	40.00	27.00
	1175	None.	162	41.00	26.00
	1177	.3	162	41.00	27.00
	1179	.6	162	41.50	27.00
	1024	3.0	....	Sour.	Color-cut.
	1026	5.0	....	Sour.	Color-cut.

[1] "c" in this column indicates raw-milk cheese.

These scores may be summarized as follows:

Table 17.—*Summary of scores in Table 16.*

Amount of starter.	Number of cheeses scored.	Average scores.		
		Flavor.	Texture.	Combined.
Per cent.				
0	3	40.83	26.33	67.16
0.25 to 0.30	7	41.64	27.53	69.18
.5 to .6	6	41.88	27.54	69.42
.75	6	42.04	27.50	69.54
1.0	2	42.12	27.25	69.37
1.25	2	42.37	27.37	69.75

These scores indicated that the cheese obtained by three-fourths, one, or one and a quarter per cent starter are about equally good, considering both flavor and texture, and the use of three-fourths per cent starter has been continued since August, 1908, to the present time, with good results. The starter used should be first class in quality, just beginning to thicken, containing the maximum number of lactic acid bacteria in active condition, and free from all objectionable germs or flavors.

Only a starter above criticism, such as every good cheese maker should know how to prepare, can be used with pasteurized milk. If the starter is at all tainted it is sure to damage the flavor of the cheese to some extent. With raw, badly tainted milk, especially in warm weather, a starter of only fair quality will often greatly improve the quality of a vat of cheese, but pasteurized milk is freed from practically all taints by the pasteurization, and to such milk only the best starter can safely be added.

The importance of a good starter was made apparent when, beginning June 9, 1910, nine days' make of pasteurized-milk cheese proved to be gassy and off flavor, and bacteriological examination of the starter as well as of the cheese demonstrated the presence of the same gas-forming organism in both. It was clear that the organisms in question did not pass through the pasteurizer, since their thermal death-point was found to be lower than the pasteurization temperature (160°) employed in the process. Therefore there could be no doubt that the improper preparation of milk for propagating "startoline" was the cause of the trouble in this case.

A PRACTICAL STERILIZER FOR THE CHEESE FACTORY.

The essential equipment for propagating a starter is some sort of a sterilizer, an incubator, and a supply of a dozen pint cream bottles which are best provided with fairly tight tin covers about 2 inches deep. Various different sterilizers have been recommended, the simplest being an inverted tin pail covering the bottles of milk on the steam table. For use as an incubator, a small covered shotgun can may be steamed out daily, and after placing the bottles therein and adjusting the cover it may be carried to the ice box, the cellar, a hay cooker, or any room of suitable temperature. Where bottles of starter must be handled and carried about there is always some danger of their becoming infected, and this can only be prevented by intelligent work on the part of the operator. On account of its small size a culture propagated in a bottle is often called a "startoline," meaning a little starter. A combined sterilizer, cooler, and incubator made of galvanized iron has been devised, and used in our work during the past year with entire satisfaction. Its use saves time in handling and reduces the danger of contamination to a minimum. It is shown in figure 1.

The apparatus consists of a galvanized-iron container with cover, a movable false bottom, and with steam, water, and drain connections. Where pint bottles are used, the perforated shelf is raised and set on lugs as shown.. If quart bottles are used, the perforated bottom is lowered, so that the top of the bottle always stands at the top of the sterilizer.

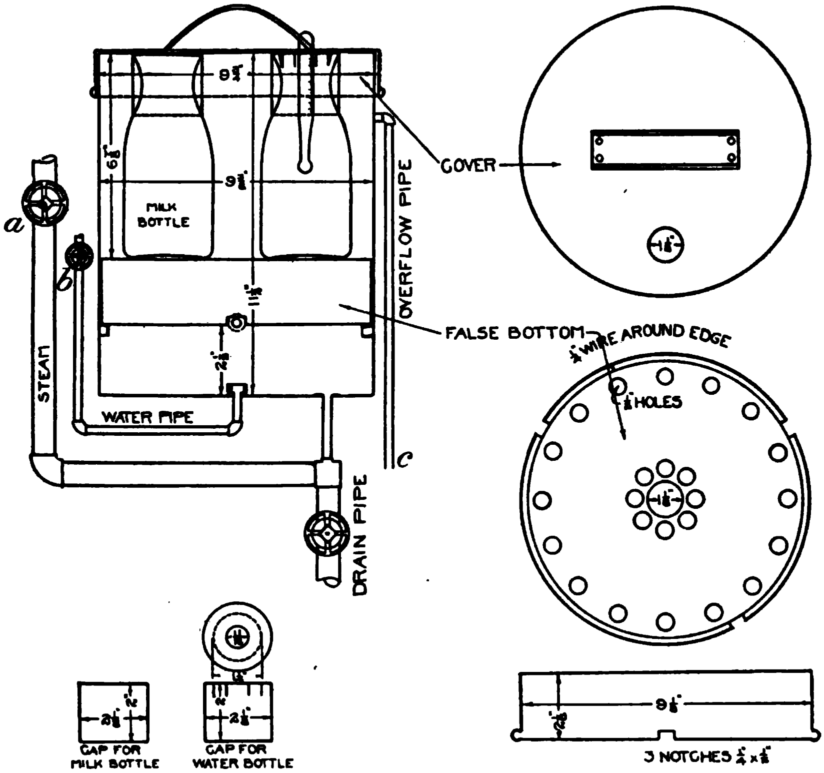


FIG. 1.—Combined sterilizer, cooler, and incubator for cheese-factory starter.

PREPARATION OF THE STARTER.

The bottles having been cleaned and filled nearly full with the best whole milk obtainable are each covered with a tin cap and set in the sterilizer, together with one bottle of water carrying the thermometer. The lid is put on and the steam turned on very slowly at first, by turning handle *a*. After the thermometer projecting through the small hole in the lid shows that the contents of the bottles are heated to 200° or above, the steam is left running for three quarters of an hour, and then turned off. To cool the bottles of sterilized milk open valve *b* and slowly run in cold water, which escapes at the overflow *c*. If the water is turned on by mistake faster than the overflow can carry it off, the tin caps will keep it from entering the bottles of milk. When the thermometer shows that the bottle contents are cooled to about 70° the water may be turned nearly or entirely off. The bottle of "startoline" from the previous day, which has not yet been opened, is now brought in and a portion, about a tablespoonful by guess, is poured into each bottle of newly sterilized milk in the apparatus, lifting the tin caps for an instant for this purpose. The room should be free from drafts, floating dust, or other source of contamination, and the transfer should be made as quickly and carefully as possible. The cap is then replaced and the cover put on. The temperature of the water can be kept between 60° and 70° for a few hours, and in the evening, in summer, if the weather is very warm, a piece of ice can be added to the water.

This daily process of propagating the "startoline" was performed in the cheese factory during the year 1911 by Mr. A. T. Bruhn, with entire success, carrying along the same culture of bacteria throughout the year. Each day after inoculating the fresh bottles of milk, the remainder is examined by pouring out a little in a teaspoon or cup, to be tasted and smelled to see that it is in good condition;[1] and if so, the remainder in the jar is used in making up starter for the next day's cheese vat in the following manner:

To prepare starter from this "startoline," place in a shotgun can about eight or nine pounds of milk for each thousand received daily, cover up, and heat in a tub or deep pail of water by passing steam until the water is boiling and a thermometer in the milk reads at least 180°. Keep it at this temperature for three-quarters of an hour and then cool by filling the tub with cold water. A dash stirrer whose handle is slipped through the smallest possible hole cut in the cover is a convenience and saves opening the can for stirring. When thoroughly cool—about 70°—add to the contents of the can the remaining contents of the "startoline" jar, as stated above. Stir this well and leave for five or six hours at this temperature, after which it may be put in a cooler place to stand overnight.

The general principle on which the temperature of starters, etc., is regulated is that the starter should ripen only fast enough so as to be barely thick, or just getting thick, when required for use next day. If the acidity increases too rapidly at first, the bacteria are kept too long before use in a highly acid medium, not favorable to their growth, and in general this is to be avoided. The thickening of the milk at about 60° or 70° may be taken as an indication that the acidity is in the neighborhood of six-tenths per cent, which is about as high as it ought to go for this purpose.

To control the temperature for ripening is not so likely to be troublesome as to avoid getting dirt and foreign bacteria into the "startoline" or starter after it has been once thoroughly sterilized.

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[1] To test further the quality of the starter, a bottle of the thickened milk, unshaken and unopened, may be set away in a warm place for a day or two, to see if gas bubbles or unpleasant flavors develop.

Strictly speaking it is impossible to sterilize milk so perfectly as to kill all spores by one such heating, and on this account attention should be given to selecting the best possible milk for starter making.

At the beginning of the season a small bottle of bacterial starter can be obtained from dealers or from a college of agriculture.

It is well to begin propagating the starter several days before cheese making is to begin, and also to carry along two or more starters from different sources, separately, in order that if one is lost or found unsuitable another may be at hand.

METHOD OF MAKING CHEESE BY THE NEW PROCESS.

GENERAL ARRANGEMENT OF SCHEDULE.

In making cheese by the new method the cheese maker is relieved of a great deal of the uncertainty which attends cheese making by the ordinary methods. Having inspected the milk at the intake and rejected any that is curdled or otherwise unfit for use, he determines by means of Manns's acid test the acidity of the entire vatful of mixed milk. This may be anywhere from 0.14 to 0.25 per cent, or even a little higher, but if much above 0.28 per cent the milk is likely to curdle and clog the pasteurizer. He then runs the milk through the pasteurizer and adds to the cold milk as it flows into the cheese vat enough dilute hydrochloric acid to raise the acidity of the whole vat to just 0.25 per cent (calculated as lactic acid). Three-quarters per cent of a first-class starter is added, and after heating to 85° the color and rennet are stirred in immediately.

The rest of the process is conducted according to a fixed time schedule, which is never varied. The time from adding rennet to hooping the curd is always exactly five hours and fifteen minutes, and the intermediate process is as shown in Table 18. This is carried on every day in the season without exception.

While it may be found desirable or convenient at some factories to modify somewhat this routine, described below, yet it appears practically certain that whatever routine of operations is adopted at any factory, it can be followed without modification throughout the season.

TABLE 18.—*Time schedule for making cheese by the new method.*

Operation.	Time interval between operations.		Total time after adding rennet.	
	H.	*m.*	*H.*	*m.*
Adding rennet	0	0	0	0
Cutting the curd	0	25	0	25
Beginning to heat	0	15	0	40
Turning off steam	0	20	0	60
Placing rack after drawing whey	1	25	2	25
Milling the curd	1	30	3	55
Salting the curd	1	00	4	55
Hooping the curd	0	20	5	15

For example, if the rennet were added to the milk at exactly 9 o'clock the curd would be ready to put in the hoops five hours and fifteen minutes later, i. e., at 2.15 in the afternoon. As soon as the rennet is added it is best to have a written schedule showing the time when each operation should be performed. Having once learned how to perform each operation in this method of cheese making it is only necessary to do everything in as uniform manner as possible in order to get satisfactory results daily throughout the season. There is never any need to hurry the process if the milk was overripe at the beginning, because the lactic-acid bacteria are practically all killed by the pasteurization. The same is also true of the gas-forming bacteria, so there is no time lost in working gas out of the curd. There is no reason for waiting to ripen the milk at the beginning of the process before adding rennet.

UNIFORM PROPORTION OF COLOR USED IN 1911, AND RENNET REQUIRED.

Color.—Throughout the season of 1911 two-thirds of an ounce of a standard make of cheese color per thousand pounds of milk was used, giving the cheese a medium shade of color. These cheeses were shipped into a number of different cities and appeared satisfactory to dealers in all parts of the country, except in Philadelphia, Pa., and Boston, Mass., where some dealers asked for white and others for highly colored cheese, as is shown by the following extracts from letters. Where more than one extract appears from the same city they are from different dealers.

Boston, Mass	Our market uses white cheese exclusively.
Boston, Mass	Use both white and colored.
Boston, Mass	A very light color would not do for this market.
Chicago, Ill	No comment on color.
Fond du Lac, Wis	A little too light color.
Geneva, N. Y	No comment on color.
Marshfield, Wis	No comment on color.
Minneapolis, Minn	No comment on color.
New York, N. Y	Color is exactly right.
New York, N. Y	Should be a trifle higher color.
Philadelphia, Pa	Have to have white cheese for Philadelphia.
Plymouth, Wis	No comment on color.
Sheboygan, Wis	A good commercial color, but might stand a trifle more color.
Sheboygan, Wis	No comment on color.
St. Louis, Mo	No comment on color.
Washington, D. C	Most of our customers want it colored.
Waterloo, Wis	No comment on color.

Rennet.—The same proportion of rennet is always used in this process, because the milk is always in the same condition as to acidity at the time of adding rennet, and always ripens equally fast afterwards. Therefore, having once selected the most suitable proportion of rennet, there is no reason for changing it. The use of 2 ounces of

Hansen's or Marschall's rennet per thousand pounds of milk is adopted as the best practice, since this quantity produces visible coagulation in 7 minutes, as shown in Table 2, and the curd is in prime condition for cutting in 25 minutes after adding rennet. If the rennet extract is weaker than it should be, such amounts should be used as will cause coagulation in the time stated.

If a larger proportion of rennet than 2 ounces per thousand pounds were used, there would hardly be time for the milk to become quiet before visible thickening began, and the curd might be damaged and broken through thickening while still in motion. On the other hand, over two years' experience with the method has shown that there is no need for using a smaller proportion of rennet than 2 ounces. Good cheese can be made with 1 ounce of rennet per thousand pounds of milk, but the coagulation of the milk is unnecessarily slow.

As in regular cheese making, great care must be taken not to measure or dilute rennet extract in any container in which there is present the least trace of cheese color, because the cheese color is strongly alkaline, and rennet loses its coagulating power almost instantly when in contact with alkalies.

ADDING STARTER, COLOR, AND RENNET TO THE MILK.

The temperature of all the mixed milk after pasteurizing is never above 85° and commonly only 70° to 80°. The acidity may be tested, if desired, and should be just 0.25 per cent, or between 0.24 and 0.26 per cent. Three-quarters of a pound of starter per hundredweight of milk in the vat is added immediately through a hair sieve, stirring the milk. The rake is then put in and the vat stirred, while heating up to 85°. The desired amount of color is stirred in, and always, without exception, the rennet is stirred in last of all. The rennet extract measured out for 5,000 pounds of milk should be diluted in a pailful of water. In adding rennet, first stir the milk across the vat the short way, going rapidly from one end of the vat to the other. With the largest-sized vats, two men with rakes may begin at the middle and walk toward the ends while stirring. Then walk back along the vat, adding the diluted rennet from a pail to the milk which is still in vigorous motion, noting on the clock the instant when the rennet first enters the milk. Set down the pail and again stir the milk across the vat the short way, with the rake or rakes, for exactly one minute, in which time the operator should be able to walk up and down the vat three or four times. In this way the smallest as well as the largest vats of milk should be set. Take out the rakes promptly one minute after the rennet entered. Cover the vat at once, and leave undisturbed. No top stirring is necessary or permissible, as the milk begins to thicken almost exactly seven minutes after adding rennet, before there is any visible cream rising. Follow exactly the directions as to temperature, acidity, and proportion of rennet every day in the season.

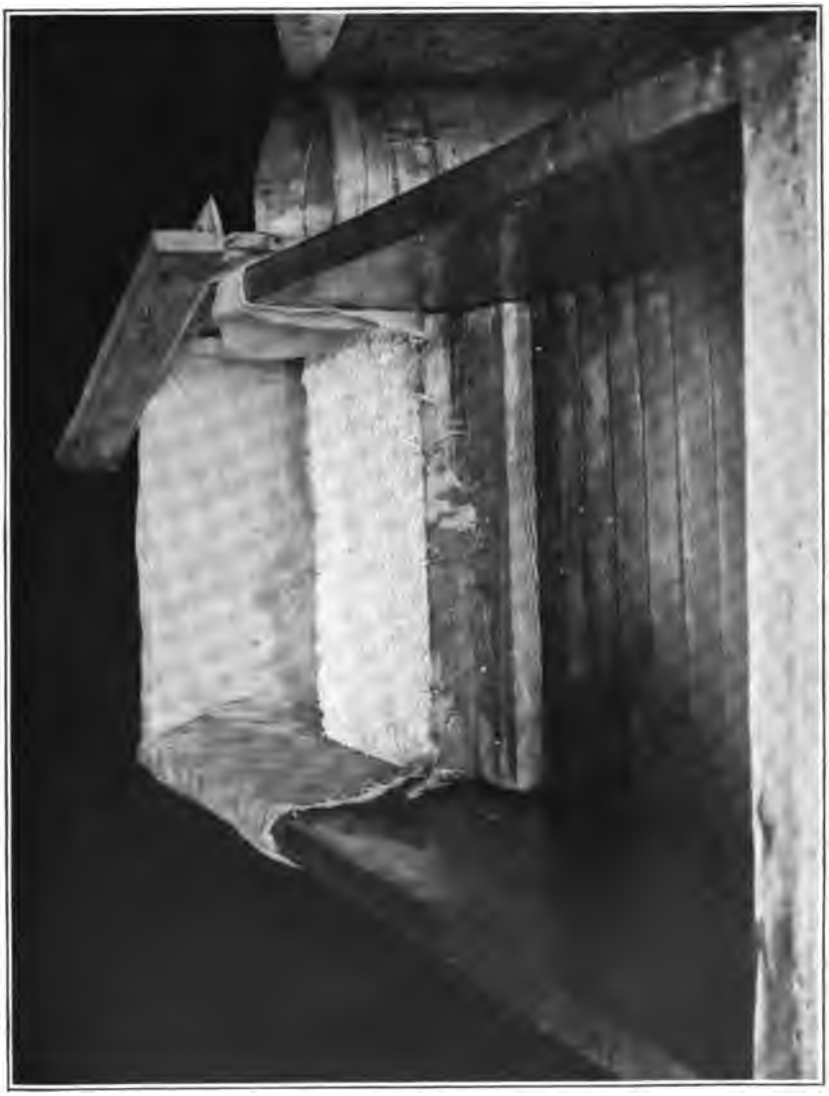
CUTTING, STIRRING, AND HEATING THE CURD.

The curd formed in this process is always ready to cut exactly 25 minutes after the rennet entered the milk. Therefore as soon as the rennet has been added it is best for the operator to write the entire time schedule, as shown in Table 18, for the rest of the day's work on a paper, or, better, on a blackboard, which can be seen across the room. Some operators may suppose that possibly the curd might be cut a little earlier or later, but experience has shown that the curd is always in a thoroughly satisfactory condition for cutting just 25 minutes after adding rennet. There is therefore no need for repeated testing of the curd with the finger; it is only necessary to keep an eye on the clock, and follow the time schedule.

In cutting, begin with the horizontal knife and cut lengthwise of the vat; then use the vertical knife across the vat, cutting alternately toward and away from the operator. Finally cut lengthwise, with the vertical knife. Do not cut the vat more than once in each direction, and try to do the cutting in exactly the same manner every day. The different cuts should not lap, nor should portions of the curd wider than three-eighths of an inch be left uncut between the knives, except in the following case: In cutting next to the sides of the vat, as in the first and last cuts in each direction, hold the knife as close to the metal sides of the vat as possible. If the knife does not appear wide enough to cut the remaining curd at the last stroke, cut close to the tin and leave a narrow strip of uncut curd, not at the edge of the vat, but between the last cut and the next to the last. This strip will be cut more thoroughly by the knives moving in other directions than if it had been left next the tin. Knives with blades three-eighths of an inch apart are required for this method.

Immediately after cutting put the agitator blades in place and start them in motion. The curd obtained in this process is so firm and solid that this can always be done safely. Go around the vat with the hand some time during the next 15 minutes, loosening the curd from the sides, bottom, and corners of the vat. A form of agitator which is very satisfactory has one pair of revolving blades which also move up and down the vat, somewhat resembling the motion of the rake.

Exactly 15 minutes after cutting turn steam into the jacket of the vat, and raise the temperature gradually during the next 20 minutes—just 19° to 104°—which temperature is maintained until the whey is drawn.



A UNIFORM LAYER OF CURD, SHOWING USE OF CURD GAUGE.

DRAWING THE WHEY, MATTING, CUTTING, AND TURNING THE CURD.

The agitator is left running until about two minutes before the whey is to be drawn, when it is removed, and the curd, after settling a few seconds, is pushed slowly away from the gate with one or two rakes. The whey strainer is placed inside the vat and the hair sieve below the gate in the conductor, the gate being opened at such a time as will permit the whey to be out and the first rack to be put in place at the time given in the schedule. When the whey is nearly all out, the gate end of the vat is lowered gradually, and a few seconds later the curd is pushed down toward the gate, leaving the upper third or half of the vat bottom bare and free from whey. In this process the curd is always sufficiently firmed in the whey so as not to need any stirring in the whey or on the rack. With reasonably brisk work the curd can be transferred to the curd cloth on the rack with a curd pail or scoop before it has time to become lumpy on the bottom of the vat. Each pail of curd as it strikes the rack should fall apart loosely and not show the presence of great lumps of curd matted together. Any such lumps should be lightly broken up with the hand, and if many lumps appear it indicates lack of skill and quickness.

The curd is piled evenly on the rack about 4 or 5 inches thick, and the top is leveled off with the hand in the usual manner and covered with a curd cloth. More racks if necessary are put in place and the vat is finally covered, leaving the curd to drain. The little curd gauge, made of wood, devised during the course of these experiments is a help in getting the layer of curd of the right thickness and also gives a good square end to the curd, which makes it easier to cut into blocks of uniform shape. (See Pl. VI.)

Just 15 minutes after the time scheduled for putting in the rack the curd gauge is removed and the cutting of the matted curd into blocks 8 inches square, or 6 by 12 inches, is begun.

The blocks are turned over immediately after cutting, and again turned 15 minutes later. They are then turned once in 10 minutes, and one hour after drawing the whey are piled two deep, and repiled every 10 minutes until milled. In turning and piling, care is always used to turn the outer cooler surfaces toward the inside, in order that the entire mass of curd may remain at practically uniform temperature throughout, as in ordinary practice.

MILLING, SALTING, AND HOOPING THE CURD.

Exactly one and a half hours after the whey is drawn the curd is milled. The milled curd is piled along the sides of the vat, so as to drain toward the middle. It is stirred up with the hands from the bottom, turning the pile over about once every 10 minutes after milling, so as to cool it somewhat, prevent matting, and allow free drainage. Little or no white whey ever escapes from the curd after milling or salting when made up by this process, although some clear whey or brine does drain away.

One hour after milling salt is thoroughly mixed with the curd at the rate of 2 pounds of salt per hundred of curd, which amounts practically to 2 pounds per thousand of milk in the spring and early summer, and 2½ pounds per thousand of milk in the fall, when the yield of cheese per hundredweight of milk is somewhat greater. The curd is stirred over several times during the next 20 minutes, by which time the salt is all dissolved, and the curd, at a temperature of 82° to 86°, is ready to be hooped. Each hoopful of curd is covered with a cloth and follower as soon as filled, in order to prevent the surface of the curd from cooling so far that it might fail to close well in the press.

It is of the utmost importance that every cheese should be well closed and develop a perfect rind, free from cracks or other openings. Where openings occur mold is sure to enter during the curing process, and the flavor especially is apt to suffer as a result.

PRESSING AND DRESSING THE CHEESE.

Throughout the present set of experiments the cheese has been pressed for about an hour, applying pressure with the hand lever only, and at first only sufficient pressure is used to keep the drippings running from the hoops. After an hour the cheese is dressed and returned to the press, when continuous pressure is put on and it is left for the night.

In bandaging the hoops, the usual starched circles are used under the heavy muslin or duck cap cloths, or if it is found that the circles are hard to remove for paraffining they may be left out and the cap cloths left on the cheese until paraffined. The cap cloths, being of heavy cloth, can be stripped off rapidly without tearing and washed; in this way they may be used many times. The next morning it is customary, as in cheese factories generally, to look over the cheese, straighten any bandages which may be faulty, and turn any crooked cheese over in the press, leaving them until noon to straighten.

DRYING, PARAFFINING, AND CURING.

The cheeses when taken from the press are stenciled with the brand and date of making or a reference number, and placed on shelves in a well-ventilated room to dry on the surface. This room may be as high as 70°. Here they are turned over once a day.

The cheese should be paraffined when 5 to 10 days old, or possibly earlier. The paraffin should be at 220° F., at least, and better at

230° to 250° F. The thinnest possible coat of paraffin is the best, and the cheese should be held in the paraffin about 5 seconds and then drawn out and left to drain over the vat, on a rack, until it can be handled. A thin coating of paraffin is flexible and less likely to crack than a thick coating.

It is possible to cure this cheese at any temperature between 34° and 75°. When it is desirable to cure the cheese as fast as possible, a temperature of 75° may be used without injury to the quality. However, at this temperature there is considerable shrinkage, and it is necessary to wipe the cheeses occasionally and turn them over to prevent them from getting moldy and sticking to the shelves.

At 45° to 55° the cheese cures well, with little shrinkage and a minimum amount of labor. It also cures well when stored at 34° at the age of 1 week and develops little or no mold on the surface, but owing to the extra cost this temperature should only be employed where it is necessary to hold the cheese for a considerable length of time.

BRANDING AND SELLING THE CHEESE.

In order that customers may be sure that they are getting genuine pasteurized-milk cheese when called for, every cheese should be marked with the words "Pasteurized cheese" running all round the edge of the cheese. All persons making cheese according to the process here described should use such a brand, in order to distinguish this product from the ordinary Cheddar cheese. A large number can be rapidly marked with a rubber stamp or by rolling the cheese over rubber type, set in a board, as shown in figure 2. Narrow strips of wood on each side of the board prevent the cheese from rolling sidewise off the type.

In a new style of product uniformity is a quality which consumers and dealers require. It is recommended that the maker of this style of cheese keep back one cheese from each day's make, when shipping, until the consignment has been accepted and paid for by the buyer. The sample cheese can then be sent along with the next shipment without plugging. If necessary, the cheese can be plugged with a trier, and by this means the maker will be able to study any faults which may be observed by the buyer and avoid them in the future. Names of leading cheese dealers who have already received sample shipments of this make of cheese and found it suitable for their trade may be obtained from the authors.

Where a maker doubts whether the buyer is giving him fair treatment, it is recommended that parts of each day's make be sent to two different dealers, whose criticisms, if any are received, can be compared by the maker at the factory.

TESTING CHEESE FOR MOISTURE WHEN DRESSED IN THE HOOP.

In making cheese by this process, the green cheese was found to differ very little in moisture content from day to day, as is shown in Table 19. Excepting the first day the cheese was made each day in two vats, and each vat of curd was tested for moisture separately.

The determination of moisture in cheese is not recommended as a part of the daily work in a factory. It is of great value, however, in experimental work, where it is desired to study the effect on their moisture content of different methods of handling curds, or the effect of different moisture content on the market value or keeping quality of cheese.

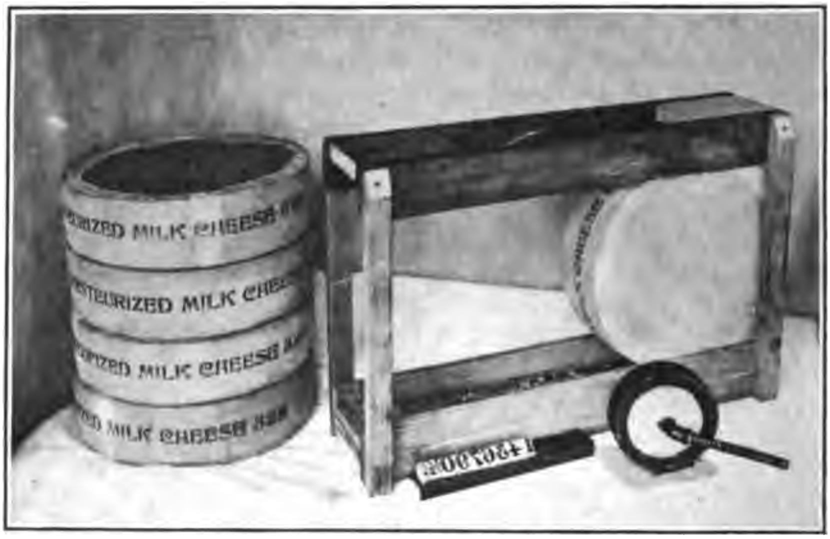


FIG. 2.—Method of marking cheese.

Moisture tests are easily made. It is objectionable, however, to plug a new cheese every day for a moisture test because of the danger of admitting molds, etc., beneath the rind, and it has been found that plugging the green cheese can be entirely avoided by sampling it at the time it is dressed in the hoop, about one hour after putting it to press. The trier hole made at this time by turning down the bandage and inserting the trier at the side will close entirely over night in the press, leaving the rind perfect. Samples of cheese thus taken from the dressed curd and tested for moisture agreed closely in moisture content with samples taken with a trier from the same cheese the next day, after pressing about twenty hours, as may be seen from Table 19.

The moisture tests were all made by heating 10-gram portions of the curd for at least three hours in the Wisconsin high-pressure steam oven.[1] After three or four hours there is practically no further loss of weight from samples of fresh curd in 24 hours' heating. Samples of cured cheese continue to lose weight with continued heating much more noticeably than samples of fresh curd or green cheese.

TABLE 19.—*Comparison of moisture determinations made on samples taken when cheese was dressed, three-quarters to one hour after pressing, and on samples taken from green cheese, next day, when removed from press.*

Date.	Moisture content when cheese was dressed.			Moisture content, next day, when removed from press.			Difference.
	First.	Second.	Average.	First.	Second.	Average.	
1911.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Aug. 15	37.60	37.40	37.50	37.95	37.25	37.60	+0.10
16	38.50	38.70	38.60	38.50	39.00	38.75	+ .15
16	38.50	38.90	38.70	38.05	38.50	38.27	− .43
17	39.60	39.10	39.35	38.50	38.60	38.55	− .80
17	38.90	39.00	38.95	39.40	39.40	39.40	+ .45
18	37.80	37.75	37.77	37.75	37.95	37.85	+ .08
18	42.25	42.25	42.25	41.25	41.40	41.32	− .93
23	38.80	38.80	38.80	38.05	38.45	38.25	− .55
23	42.25	42.45	42.35	42.20	42.10	42.15	− .20
24	39.35	39.05	39.20	39.70	40.30	40.00	+ .80
24	44.25	44.30	44.27	43.15	43.30	43.22	−1.05
25	39.55	39.70	39.62	39.30	39.65	39.46	− .16
25	44.10	44.45	44.27	44.25	44.95	44.60	+ .33
26	38.95	39.10	39.02	38.80	39.00	38.90	− .12
26	44.30	44.60	44.45	42.80	43.00	42.90	−1.55

RESULTS OF TWO YEARS' TRIAL OF THE METHOD.

INCREASED YIELD OF CHEESE OBTAINED BY THE NEW PROCESS.

APPARATUS AND METHODS OF STUDY.

In the season 1909–1910 it was found that an increased weight of cheese is regularly obtained after pasteurization as compared with the weight obtained by the regular factory methods. For the purpose of accurately studying the yield of cheese in 1911 two scales were used, one of 5,000 pounds' capacity graduated on the beam to one-half pound and one of 300 pounds' capacity graduated on the beam to one-tenth pound. The larger scale was set up permanently in one corner of the make room, and a wooden frame carrying a 300-gallon steel receiving vat was placed upon it. The outlet of the vat is of sanitary metal piping, suspended by wire to the vat in such a way that the pipe and contents are weighed each time with the vat. The frame, vat, and pipe weighed 487½ pounds when empty. The separate weights and the scale on the beam were carefully tested by use of test weights. The entire set of weights agreed among themselves so closely that no difference could be detected in the equilibrium of the beam when one weight was substituted for another in weighing a load. The error in a single weighing is not over one-quarter of a pound with large or small loads. Except when weighing the lever is kept up, thus relieving the knife edges from load and wear.

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[1] Farrington, E. H. A creamery method for the determination of water in butter. Wisconsin Agricultural Experiment Station, Bulletin 154. Madison, Sept., 1907.

The method of using this apparatus is as follows: The vat being empty with the pipes in place and stopcocks closed, the supply of milk is run into the vat through a conductor and cloth strainer. The strainer and conductor are then removed, the lever is lowered, and the weight of vat and contents determined. It is our habit to balance the scales exactly, giving neither "up" nor "down" weight. The lever is then raised, and the operator climbs up the ladder on the frame to the runboard along the side of the vat. With a dipper he stirs the milk continuously and vigorously for 5 or 10 minutes, and continues stirring while a portion of the milk is being drawn out for use in one of the experimental cheese vats. The vat and the remaining milk are then weighed with the same precautions as before, after which another portion of the milk may be drawn off for use in another vat in the same manner.

The precautions mentioned above seemed sufficient to insure that the milk used in the two vats—one for ordinary and one for pasteurized cheese—was thoroughly mixed at the time it was drawn from the receiving vat, and that each lot was weighed accurately with a total possible error of not over one-half a pound in a vat of 200 to 2,000 pounds of milk—an error of one-fortieth to one-fourth of 1 per cent, at most.

The other new scale mentioned above is a counter scale graduated on the beam to one-tenth of a pound and sensitive to one-twentieth of a pound with any load up to 200 pounds. This was used for weighing the cheese throughout the work here described. The set of weights used with this scale agreed among themselves and with the test weights mentioned above in the description of the other scale.

With the smaller scale, 20 to 200 pounds of cheese could readily be weighed with an error of not over 0.05 of a pound, or 0.25 per cent, at most. On 68 days during the season of 1911 the receiving vat of milk was divided into two accurately weighed portions for this experiment. One of these was pasteurized and made up into cheese by the new method, the other portion was made up into cheese by regular factory methods. The cheese was 13½ inches in diameter by 4 inches high, the "daisy" size. The green cheese was always weighed as quickly as possible after being removed from the hoops. The daily record of weights of milk used and of cheese obtained, and the per cent of increased yield which resulted from pasteurization, are shown in Table 20.

TABLE 20.—*Increased yield of green cheese obtained by the new method from pasteurized milk.*

Date made.	Pasteurized milk.			Raw milk.			Gain by pasteurized milk.	Proportion of starter used.	
	Milk used.	Green cheese.	Yield of cheese per hundredweight of milk.	Milk used.	Green cheese.	Yield of cheese per hundredweight of milk.		Pasteurized.	Raw.
1911.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Per cent.*	*Per ct.*	*Per ct.*
Feb. 23	538.0	53.20	9.89	380.0	35.40	9.31	6.23	0.75	0.00
24	504.5	51.00	10.11	380.0	36.60	9.63	4.98	.75	.00
27	1,026.5	106.20	10.35	600.0	57.80	9.63	7.48	.75	.00
28	800.0	82.20	10.27	400.0	38.30	9.57	7.31	.75	.75
Mar. 1	350.0	35.40	10.11	510.0	50.20	9.84	2.75	.75	1.50
2	389.5	39.60	10.01	628.0	59.70	9.51	6.61	.75	.75
3	340.0	35.00	10.29	522.0	52.30	10.02	2.79	.75	1.50
7	855.0	88.20	10.32	380.0	38.40	10.11	2.08	.75	2.00
8	590.0	60.70	10.29	388.5	39.30	10.12	1.68	.75	1.50
9	418.0	42.80	10.24	417.5	41.60	9.82	4.27	.75	1.00
10	442.0	44.70	10.11	700.0	66.40	9.49	6.53	.75	.00
13	1,166.0	122.00	10.46	275.0	25.70	9.34	12,00	.75	.00
14	956.0	103.40	10.81	260.0	25.80	9.92	8.97	.75	.75
15	570.5	58.10	10.18	380.0	37.50	9.87	3.14	.75	.75
16	531.5	56.90	10.71	359.0	37.40	10.42	2.78	.75	2.00
17	395.0	41.20	10.43	396.0	39.80	10.05	3.78	.75	2.50
20	1,344.0	136.00	10.12	384.0	36.60	9.53	6.19	.75	.00
21	570.0	56.40	9.89	378.0	35.30	9.34	5.89	.75	.00
22	362.5	36.00	9.93	542.0	51.80	9.56	3.87	.75	1.67
Apr. 5	585.0	60.80	10.39	390.0	37.70	9.67	7.45	.75	.75
7	508.0	51.15	10.07	339.5	32.50	9.57	5.22	.75	.75
11	549.0	55.00	10.02	549.0	52.60	9.58	4.59	.75	.75
13	364.0	35.70	9.81	364.0	34.55	9.49	3.37	.75	.75
17	800.0	80.25	10.03	600.0	55.50	9.25	8.43	.75	.00
18	720.0	71.15	9.88	540.0	49.80	9.22	7.16	.75	.00
24	1,254.0	122.80	9.79	660.0	61.90	9.38	4.37	.75	.75
27	570.0	55.30	9.70	380.0	35.70	9.39	3.30	.75	.75
28	420.0	40.85	9.73	420.0	40.05	9.54	1.99	.75	.75
May 2	636.0	65.05	10.23	424.0	42.00	9.91	3.23	.75	.75
3	558.0	54.30	9.73	372.0	35.55	9.56	1.81	.75	.75
8	1,693.0	158.15	9.34	800.0	70.95	8.87	5.30	.75	.75
10	798.0	77.60	9.72	798.0	73.70	9.24	5.19	.75	.75
15	1,587.0	161.60	10.18	800.0	76.90	9.61	5.93	.75	.75
17	1.088.5	109.00	10.01	800.0	76.60	9.57	4.60	.75	.75
22	1,223.0	129.40	10.58	800.0	78.20	9.77	8.29	.75	.75
25	851.0	87.00	10.22	800.0	78.80	9.85	3.76	.75	.75
29	1,315.0	138.60	10.54	800.0	80.20	10.02	5.29	.75	.75
June 1	798.0	83.50	10.46	800.0	83.10	10.39	.67	.75	.75
2	799.5	82.85	10.36	800.0	79.50	9.94	4.23	.75	.75
7	790.5	79.65	10.07	800.0	76.60	9.57	5.22	.75	.75
9	800.0	82.30	10.29	800.0	78.15	9.77	5.32	.75	.75
13	1,090.0	119.70	10.98	800.0	80.20	10.02	9.58	.75	.00
15	795.0	85.50	10.75	800.0	80.70	10.09	6.54	.75	.75
16	800.0	83.45	10.43	800.0	78.95	9.87	5.67	.75	.75
19	810.0	87.60	10.81	800.0	79.65	9.96	8.54	.75	.00
21	798.5	81.75	10.24	800.0	77.70	9.71	5.46	.75	.75
26	770.0	80.65	10.47	770.0	75.45	9.80	6.84	.75	.00
27	801.0	83.50	10.42	800.0	79.00	9.88	5.46	.75	.75
28	801.5	85.90	10.73	800.0	82.00	10.25	4.68	.75	.75
July 3	1,234.0	122.75	9.95	800.0	72.35	9.04	10.07	.75	.00
6	995.0	102.45	10.30	660.0	66.10	10.02	2.79	.75	.75
8	1,068.0	108.50	10.16	660.0	62.80	9.52	6.72	.75	.00
10	1,064.5	107.30	10.08	800.0	74.35	9.29	8.50	.75	.00
11	914.0	93.50	10.23	660.0	63.65	9.64	6.12	.75	.00
12	873.0	93.15	10.67	800.0	78.20	9.77	9.21	.75	.75
24	1,195.0	125.10	10.47	600.0	58.20	9.70	7.94	.75	.75
26	1,099.0	118.32	10.77	190.0	19.32	0.17	5.90	.75	.00
Aug. 29	294.5	31.58	10.72	290.0	30.50	10.52	1.90	.75	.75
30	344.0	35.82	10.41	340.0	34.05	10.01	4.00	.75	.75
Sept. 1	322.0	34.10	10.59	320.0	32.60	10.19	3.92	.75	.75
5	291.5	31.00	10.63	292.0	29.65	10.15	4.73	.75	.75
6	276.0	28.95	10.49	275.0	27.20	9.89	6.46	.75	.75
7	286.5	31.03	10.83	286.5	29.48	10.29	5.24	.75	.75
8	292.0	31.50	10.79	292.0	30.25	10.36	4.14	.75	.75
20	263.0	29.15	11.08	263.0	27.80	10.57	4.82	.75	.75
22	265.0	29.20	11.02	266.5	28.05	10.52	4.75	.75	.75
25	748.0	83.90	11.22	250.0	26.40	10.56	6.25	.75	.75
Oct. 2	700.5	79.25	11.31	420.0	45.10	10.74	5.31	.75	.75
3	251.0	27.75	11.05	250.0	26.25	10.50	5.24	.75	.75
Average..	....	....	10. 7	....	....	9.815	5.374	....	....

It will be noted that every day in the season there was a greater yield of cheese from the pasteurized milk. From 250 to 1,700 pounds of milk were handled in each vat. The average yield of green cheese from raw milk was 9.815 pounds and from pasteurized milk 10.337 pounds per hundred pounds of milk.

The daily increase in yield ranged from 0.6 per cent to 12 per cent, and in 50 cases (72 per cent) lay between 3 and 8 per cent, while the average increase in yield by the new process on 69 days was 5.37 per cent.[1] On 45 days the same proportion of skim milk starter—three-fourths per cent—was used in both the raw and the pasteurized milk. In the raw milk none was used on 16 days, and on 8 days 1 to 2½ per cent (on the average 1.71 per cent) was used, while in every case the pasteurized milk received three-fourths per cent starter. If the use of starter affects the yield of cheese, the average yield from the pasteurized milk on 16 days was raised about three-fourths per cent, while the average yield from raw milk was raised on 8 days about 1.71 per cent. These two effects offset each other in the table, giving a slight advantage to the yield from the raw milk, so that the final average figure—5.37 per cent—representing the average gain in yield of green cheese by the new process, is no higher and possibly a trifle lower than it would have been if equal proportions of starter had been used in all cases.

Among the 17 cases in Table 20 in which no starter was used in the raw-milk vat, the average gain in the pasteurized-milk vat, using three-fourths per cent starter, was 7.48 per cent; and in 8 cases where more than three-fourths per cent starter was used in the raw milk, the average gain in yield in the pasteurized-milk vat was 3 per cent. From this it would appear that the proportion of starter used does notably affect the yield of cheese, contrary to some recent statements.[2]

SEARCH FOR SYSTEMATIC ERRORS IN EXPERIMENTS ON YIELD OF CHEESE.

The presence of systematic errors was carefully guarded against in the daily work on the yield of cheese. Before dividing the milk from the receiving vat for use in the two make vats, the milk was first thoroughly stirred for 4 to 10 minutes, as already stated, and the stirring was continued while the milk was running out. The portion of milk drawn out first was commonly used for making the raw-milk cheese, but sometimes, as on March 8, 9, 10, 17, 21, 22, and April 7, 11, 17, 18, and May 10, the portion drawn first was used for making the pasteurized-milk cheese. The average gain in yield through pasteurization on these 11 days was 5.15 per cent, so nearly equal to the general average of 5.37 per cent (see Table 20) as to indicate that the gain in yield is not due to any difference in composition of the milk when divided into two lots. Carefully tested thermometers and the same pair of curd knives were used in every vat.

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[1] Both the median and the mode lie between 5 and 6 per cent. The mode is the class which occurs with the greatest frequency; the median is the magnitude at the middle of the series from largest to smallest. See "Statistical Methods," by C. B. Davenport, New York, 1899, or "Principles of Breeding," by E. Davenport, Boston, 1907, p. 684.

[2] Van Slyke, Lucius L., and Publow, Charles A. The science and practice of cheese making. New York, 1909. See p. 69.

Usually the vat of pasteurized milk was set first with rennet, and the vat of raw milk 5 minutes later. The two vats were placed near each other, and conditions were such that one operator could stir them both at once, if desired. On 11 days, April 18, 24, 27, May 8, 10, 15, 17, August 29, 30, September 1, and October 2, the rennet was added to the raw milk first, and to the pasteurized milk 5 minutes later. The average gain in yield on the 11 days was 4.63 per cent, indicating that the order of setting the vats had nothing to do with the gain in yield.

In order to ascertain what per cent of unavoidable error enters into the measurement of yield of cheese, a special experiment was performed on 34 days. Each day, with all of the usual precautions, two lots of milk drawn from the receiving vat were run through the pasteurizer, one after the other, and made up into cheese in separate vats marked (C) and (D) standing near each other, and handled by the same operator (Mr. Bruhn). The vats were heated and set exactly 5 minutes apart by the watch, and the time schedule for each vat was strictly followed in every detail. The same curd knives and thermometer were used in both vats.

The pasteurizer and cooler are always rinsed with hot water at the beginning of the first run, but are wet with adhering milk at the close of the run just before beginning the second run. Thus the actual weight of milk in the first vat might be slightly less than it should be. To avoid this source of error, the pasteurizer and cooler were allowed to drain each time into the vat for several minutes (until the stream of milk broke into single drops), and then the metal surfaces were carefully rinsed with two measured portions of clean water. Thus the surfaces of the pasteurizer and cooler were wet with water at the beginning of the second run as well as the first. The milk content of the rinsings (see Table 21) was found to be very small and uniform, amounting to about 0.8 of a pound of milk each time, which if it were all lost from one vat but not the other would cause a difference of yield of cheese from a 500-pound lot of milk (as in Table 22) of about 0.16 per cent. In order to avoid this source of error entirely, the rinsings from both runs were either thrown away, as on the first 15 days listed in Table 22, or the rinsings after each run were added to the respective vats, as on the last 19 days.

TABLE 21.—*Milk content of rinsings of pasteurizer and cooler.*

Date.	Weight of rinsings.	Fat content.		Estimated weight of cheese in rinsings.	Estimated weight of milk in rinsings.
		Per cent.	Weight.		
1911.	*Pounds.*		*Pounds.*	*Pounds.*	*Pounds.*
Apr. 25 (Vat C)	2.25	1.25	0.028	0.08	0.8
25 (Vat D)	2.25	1.25	.028	.08	.8
26 (Vat C)	2.25	1.20	.027	.08	.8
26 (Vat D)	2.25	1.20	.027	.08	.8

The yield of cheese obtained in duplicate vats thus handled was never exactly equal and varied on the average for 33 days by 0.585 per cent of the weight of the cheese, as shown in Table 22. The milk in Vat C was drawn first from the receiving vat, and was pasteurized and set first in all cases except where otherwise noted.

TABLE 22.—*Variation in yield of cheese from duplicate vats of pasteurized milk.*

Date.	Vat C.			Ratio of milk weights.		Vat D.			Difference in yield of the two vats.
	Weight of milk used.	Weight of green cheese.	Cheese per cwt. of milk.			Weight of milk used.	Weight of green cheese.	Cheese per cwt. of milk.	
1911.	*Pounds.*	*Pounds.*	*Pounds.*	*Vat C.*	*Vat D.*	*Pounds.*	*Pounds.*	*Pounds.*	*Per cent.*
Mar. 23	430.0	42.50	9.884	1	1	430.0	42.55	9.895	0.11
24	390.0	38.80	9.949	1	1	390.0	39.10	10.026	.77
27	375.0	36.10	9.627	1	3	1,125.0	109.20	9.707	.83
28	350.0	36.60	10.457	1	2½	875.0	92.20	10.537	.76
29	585.0	59.10	10.102	1½	1	390.0	39.45	10.115	.13
30	495.0	50.10	10.121	1½	1	330.0	33.50	10.151	.30
31	540.0	54.20	10.038	1½	1	360.0	36.15	10.042	.04
Apr. 4	585.0	60.50	10.342	1½	1	390.0	40.55	10.397	.53
6	534.0	54.15	10.140	1½	1	356.0	37.35	10.491	[1]3.46
10	1,080.0	106.30	9.842	3	1	360.0	35.65	9.903	.62
12	555.0	55.70	10.036	1½	1	370.0	37.60	10.162	1.25
14	380.0	38.10	10.026	1	1	380.0	38.40	10.105	.79
19	400.0	40.30	10.075	1	1	400.0	40.60	10.150	.74
20	370.0	36.75	9.932	1	1½	555.0	55.40	9.728	.50
21	380.0	37.00	9.737	1	1½	570.0	55.45	9.728	.09
25	420.0	41.00	9.762	1	1	420.0	40.90	9.738	.25
26	370.0	36.20	9.784	1	1½	555.0	54.35	9.793	.09
May 4	420.0	42.10	10.024	1	1	420.0	42.50	10.119	.95
5	531.0	51.40	9.680	1½	1	354.0	34.35	9.703	.24
9	408.0	40.65	9.963	1	1½	612.0	60.80	9.935	.28
11	410.0	41.50	10.122	1	1	410.0	41.80	10.195	.72
12	795.0	78.25	9.843	1	1	795.0	79.50	10.000	1.59
16	800.0	80.30	10.037	1	1	800.0	80.65	10.081	.44
18	600.0	63.80	10.633	1	1	600.0	62.70	10.450	1.75
19	600.0	62.20	10.367	1	1	600.0	61.95	10.325	.41
23	600.0	64.00	10.667	1	1	600.0	63.75	10.625	.39
24	612.25	64.35	10.510	1	1	612.25	65.15	10.641	1.24
30	600.0	61.30	10.217	1	1	600.0	60.75	10.125	.91
31	600.0	62.10	10.350	1	1	600.0	62.12	10.353	.03
June 6	583.0	59.15	10.146	1	1	577.75	59.15	10.238	.91
8	600.0	61.55	10.258	1	1	600.0	61.85	10.308	.49
14	600.0	62.28	10.380	1	1	600.0	62.15	10.358	.21
17	599.5	62.71	10.460	1	1	599.5	63.11	10.527	.64
20	600.0	60.30	10.050	1	1	600.0	60.90	10.150	.99
Average	535.22	....	10.105	....		536.37	....	10.149	[1].585

[1] The result for Apr. 6 is omitted in computing the average because of abnormal conditions.

Among the 34 days' results obtained during the season, as shown in Table 22, the difference in yield between duplicate vats exceeded 1.75 per cent in only one case. On this day there was unusual difficulty in the work because of unexpected failure of the supply of water for cooling, and, although the direct cause of the exceptionally high figure (3.46 per cent) can not be directly traced, it seems likely that some gross error occurred, which was avoided on the other days. Therefore this figure (for April 6) is omitted from the general average.

On 28 days (82 per cent of all cases) the variation in yield between duplicate vats lay below 1 per cent and on 33 days (omitting April 6) it averaged 0.584 per cent. For present purposes, therefore, it may be considered that the figure 5.37 per cent, from Table 20, representing the average increased yield of green cheese obtained through pasteurization, is correct within 0.58 per cent, or about one-ninth of its value.

The yield of cheese from pasteurized milk is thus capable of measurement with an average difference between duplicate determinations of 0.6 per cent of the amount determined. This degree of accuracy in manipulation is comparable with that attained in many analytical chemical processes, in which a limit of 1 per cent of the amount determined is commonly set as the maximum allowable difference between duplicates.

The principal cause for the difference of 0.60 per cent in the yield in making duplicate vats of cheese does not lie in the weighing of the milk or cheese, because with the scales employed both the milk used and the cheese obtained therefrom could be weighed with an error of not over 0.10 per cent. The per cent of difference in yield was not reduced when the weight of milk handled was increased. It appears likely, therefore, that there are small unavoidable differences caused by the size of the cubes or in the manipulation of the milk and curd which cause an average difference in yield of from 0.50 to 0.60 per cent between duplicate vats.

An effort was made so far as time permitted to determine whether any one of several causes was regularly or chiefly responsible for this average difference in the yield. The stirring of the vats was done by hand in all cases where the weight of milk in a vat was less than 400 pounds. For experiments with 400 to 800 pounds of milk in a vat a pair of vats of 800 pounds capacity was used. These were stirred with a pair of wooden rakes, exactly alike in shape and size. Larger quantities of milk than 800 pounds were always handled in a vat of 2,400 pounds capacity in which a two-bladed rotating and oscillating agitator was used instead of the rake. The difference in yield between duplicate vats could not be traced to the methods of stirring. Thus, on March 27, the agitator-stirred vat (D) gave 0.83 per cent greater yield than the hand-stirred vat (C), but on April 10 the hand-stirred vat (D) gave 0.62 per cent greater yield than the agitator-stirred vat (C). The average difference on 12 days in yield between duplicate rake-stirred vats was 0.70 per cent, and the average difference in yield between duplicate hand-stirred vats on 19 days was 0.52 per cent. The differences varied slightly whatever method of stirring was employed.

Again, handling different amounts of milk did not appear to affect the yield in duplicate vats. On 12 days, using one and one-half to three times as much milk in one vat as in the other, the average difference in yield was 0.40 per cent, which is a little smaller than the average of the other days, showing that the quantity of milk handled by this method does not affect the yield. Since the same results are obtained in a small vat with 375 pounds of milk as in a large one with 1,125 pounds of milk, it is believed that the general results of this investigation are applicable to the largest sized vats of milk used in factories.

SHRINKAGE BEFORE PARAFFINING, AND YIELD OF PARAFFINED CHEESE.

Since there is always some loss in weight of cheese previous to paraffining, it is of interest to compare the shrinkage of ordinary cheese with that of new-process cheese, and to determine whether there is an increased yield of pasteurized-milk cheese when paraffined corresponding to the increased yield observed in the same cheese when green. This can be done readily from Table 23, which shows the average results for the season and also the range of daily variation.

TABLE 23.—*Comparison of old and new process cheese as to shrinkage before paraffining and yield of paraffined cheese.*

Date made.	Age when paraffined.	Shrinkage per 100 pounds of green cheese before paraffining.		Yield per 100 pounds of milk.		Gain in yield by new process.
		Pasteurized.	Raw.	Pasteurized.	Raw.	
1911.	*Days.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Per cent.*
Feb. 23	19	5.92	5.23	9.30	8.83	5.32
24	18	5.98	5.05	9.50	9.14	3.94
27	15	5.32	4.67	9.79	9.18	6.64
28	14	5.23	4.57	9.74	9.14	6.56
Mar. 1	13	5.36	4.88	9.57	9.36	2.24
2	12	5.26	4.35	9.49	9.09	4.40
3	15	5.71	5.35	9.71	9.48	2.43
7	11	5.21	4.43	9.78	9.66	1.24
8	10	4.45	4.58	9.83	9.65	1.86
9	9	5.49	4.82	9.68	9.35	3.53
10	8	3.58	3.35	9.75	9.17	6.32
13	12	5.08	4.28	9.93	8.95	10.95
14	11	5.13	4.26	10.26	9.50	8.00
15	10	3.96	3.73	9.78	9.50	2.95
16	9	4.22	3.61	10.25	10.04	2.09
17	8	3.88	3.27	10.03	9.72	3.19
20	12	5.37	4.37	9.58	9.11	5.16
21	11	4.42	3.68	9.46	8.99	5.23
22	10	4.72	3.86	9.46	9.19	2.94
Apr. 5	10	4.36	3.58	9.94	9.32	6.65
7	8	4.10	3.85	9.66	9.20	4.60
11	10	5.09	4.56	9.51	9.14	4.05
13	8	4.62	4.05	9.35	9.11	2.63
17	12	5.11	4.23	9.52	8.86	7.45
18	11	4.85	4.42	9.40	8.81	6.70
24	12	5.05	4.11	9.30	8.99	3.45
27	9	3.98	3.64	9.32	9.05	2.98
28	8	2.82	2.62	9.45	9.29	1.72
May 2	11	4.36	3.93	9.79	9.52	2.84
3	10	4.33	4.08	9.31	9.17	1.53
8	13	4.52	4.65	8.91	8.46	5.32
10	11	4.19	3.73	9.32	8.89	4.83
15	12	4.64	4.36	9.71	9.19	5.65
17	10	4.57	3.98	9.49	9.19	3.26
22	12	4.71	4.09	10.08	9.37	7.57
25	11	4.71	3.93	9.74	9.46	2.96
29	13	4.72	4.37	10.04	9.59	4.69

TABLE 23.—*Comparison of old and new process cheese as to shrinkage before paraffining and yield of paraffined cheese*—Continued.

Date made.	Age when paraffined.	Shrinkage per 100 pounds of green cheese before paraffining.		Yield per 100 pounds of milk.		Gain in yield by new process.
		Pasteurized.	Raw.	Pasteurized.	Raw.	
1911.	*Days.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Per cent.*
June 1	10	3.92	3.67	10.05	10.01	0.40
2	9	4.22	3.92	9.93	9.55	3.98
7	7	4.21	3.66	9.66	9.22	4.77
9	8	3.80	3.58	9.90	9.42	5.09
13	10	5.26	4.74	10.40	9.55	8.90
15	8	4.49	3.82	10.18	9.70	4.95
16	7	4.43	3.64	9.97	9.51	4.84
19	12	4.85	4.27	10.29	9.53	7.97
21	10	4.46	4.18	9.78	9.31	5.05
26	12	4.53	4.17	10.00	9.40	6.38
27	11	4.19	3.80	9.99	9.50	5.16
28	10	4.02	3.41	10.30	9.90	4.04
July 3	14	4.56	3.91	9.49	8.69	9.21
6	11	4.20	4.01	9.86	9.61	2.60
8	9	3.64	3.42	9.79	9.19	6.53
10	10	4.80	4.64	9.60	8.86	8.35
11	11	4.46	4.01	9.77	9.26	5.51
12	10	4.54	3.65	10.19	9.42	8.17
Aug. 29	11	4.99	6.07	10.18	9.88	3.14
30	10	4.22	4.05	9.97	9.61	3.75
Sept. 1	8	4.14	4.14	10.15	9.77	3.89
5	13	4.35	4.05	10.17	9.74	4.42
6	12	3.82	3.49	10.09	9.54	5.65
7	11	3.49	2.99	10.45	9.98	4.71
8	10	3.17	2.81	10.45	10.07	3.77
20	10	3.80	3.41	10.66	10.21	4.41
22	8	3.43	3.21	10.64	10.19	4.42
25	16	6.49	5.87	10.49	9.94	5.53
Average..	....	4.546	4.078	9.833	9.388	4.761

In practically every case in Table 23 the pasteurized-milk cheese showed a greater shrinkage than the raw-milk cheese during the period before paraffining, which was 7 to 19 days. The average shrinkage of raw-milk cheese before paraffining, for all 65 cases, was 4.08 pounds per hundred of green cheese, and for the pasteurized-milk cheese it was 4.55 pounds per hundred, nearly one-eighth greater than the raw. This excess shrinkage is observed whether the cheese was paraffined at 7 or 14 days, as is shown in the following table, which is a summary of Table 23.

TABLE 24.—*Shrinkage of cheese when paraffined at different ages* (*summary of Table 23*).

Age when paraffined.	Cases averaged.	Average shrinkage in weight per 100 pounds green cheese.		Excess in pasteurized.	
		Pasteurized.	Raw.		
Days.	*Number.*	*Pounds.*	*Pounds.*	*Pounds.*	*Per cent of raw.*
7 to 8	11	3.95	3.56	0.39	11
9	5	4.31	3.88	.43	11
10	16	4.35	3.83	.52	13
11	12	4.52	4.10	.42	11
12	10	4.84	4.17	.67	16
13 to 19	11	5.29	4.78	.51	11

On account of this excess shrinkage before paraffining, amounting to about one-half pound per hundred pounds of cheese, the average increased yield of 5.37 pounds per hundred of milk observed in the pasteurized cheese when green (Table 20) was reduced to 4.76 pounds (see Table 23) by the time the cheese was paraffined.

SHRINKAGE AND YIELD OF CURED CHEESE.

The further shrinkage and yield of cheese after paraffining was studied: (1) With cheese cured at Madison, Wis., at a temperature of 60° to 75°; (2) with cheese cured at New Orleans, La., and weighed both at New Orleans[1] and Madison; (3) with cheese cured at New Orleans or at Columbus, Ga., and weighed both at Chicago and at Madison; (4) with cheese cured in a warm room at Madison; and (5) with cheese put in cold storage at 34° F. at Waterloo, Wis., at different ages after paraffining. So far as possible duplicate cheeses from the same days' make were cured in the different ways stated.

These different methods of curing were chosen for study as representing (1) curing conditions at Wisconsin factories; (2), (3), and (4) conditions to which annually large amounts of cheese are subjected when shipped south for sale; and (5) when cured in cold storage as commonly practiced by dealers.

The shipments to New Orleans were sent on four dates between April 29 and July 24, 1911. Each shipment consisted of 9 to 25 pasteurized-milk cheeses, and an equal number of raw-milk cheeses for comparison. In order that the cheese stored might be as representative as possible, each pair represented a different day's make.

For each lot of cheese shipped away from Madison for storage, a duplicate lot from the same days' make was kept at Madison. The method of designating these different lots of cheese is shown in Table 25:

TABLE 25.—*Reference numbers to different lots of cheese stored in 1911.*

Date made.	Cheese Nos.	Cured at Madison.	Cured at New Orleans.	Cured at New Orleans and Columbus, Ga.	Cured in warm room at Madison.	Cured at Waterloo, Wis.
Feb. 23 to Apr. 16	171 to 207	1A	1B			
Apr. 24 to May 17	211 to 227	2A	2B			
May 22 to June 16	230 to 246	3A	3B	3C	3D	
June 19 to July 12	248 to 263	4A	4B	4C	4D	
July 13 to Aug. 21	264 to 283	5A				5E

In addition to weighing each cheese separately they were also weighed in lots of five, and the close agreement of the weight of a lot of five with the sum of the five separate weights proved the accuracy of the weighing. This general method of double weighing was followed in obtaining all the weights of cheese in the 14 lots.

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[1] The details of the work at New Orleans connected with the storage, weighing, and shipping of the cheese used in this test were handled by Mr. W. J. Bleecker, junior dairyman of the Dairy Division, Bureau of Animal Industry. Thanks are due to Mr. Bleecker for his very careful attention to this work.

The tabulated results show the shrinkage of the different lots and the yield of green, paraffined, and cured cheese per hundred pounds of milk. In addition to the average results for each lot of cheese, the individual variations in shrinkage and yield of the single cheeses are shown, from which the extent of daily variations from the general average figures can be studied by anyone interested.

Cheese cured at Madison (lots 1A to 5A).—Fifty-two pairs of cheese cured at 60° to 70° were weighed one or more times (92 times in all) at different ages, from 21 to 117 days after paraffining. In every case there was a gain in yield of pasteurized cheese over raw cheese. The gain averaged 4.59 per cent among 10 pairs of cheese cured 20 to 30 days, 4.58 per cent among 37 pairs of cheese cured 30 to 60 days, 4.38 per cent among 28 pairs of cheese cured 60 to 90 days, and 3.58 per cent among 17 pairs of cheese cured 90 to 117 days. On the average of all cases the gain in yield of pasteurized over raw was 4.22 per cent of the weight of the cheese.

TABLE 26.—*Comparison of yield of raw and pasteurized-milk cheese after curing for various lengths of time at Madison, Wis.*

Date made.	Time cured after paraffining.	Weight of cured cheese per 100 pounds of milk.		Gain by pasteurization.	
		Pasteurized.	Raw.		
1911.	*Days.*	*Pounds.*	*Pounds.*	*Pounds.*	*Per cent.*
Apr. 24	21	9.27	8.96	0.31	3.46
Mar. 20	26	9.52	9.06	.46	5.08
21	26	9.40	8.94	.46	5.15
22	26	9.37	9.12	.25	2.74
20	33	9.47	8.99	.48	5.34
17	32	9.87	9.63	.24	2.49
16	32	10.02	9.96	.06	.60
15	32	9.68	9.38	.30	3.20
14	32	10.03	9.34	.69	7.38
13	32	9.72	8.80	.92	10.46
2	42	9.53	9.36	.17	1.81
7	42	9.57	9.49	.08	.84
8	42	9.61	9.51	.10	1.05
9	42	9.55	9.29	.26	2.80
10	42	9.62	9.09	.53	5.83
Apr. 17	42	9.30	8.73	.57	6.54
18	42	9.13	8.64	.49	5.67
May 15	44	9.43	8.89	.54	6.07
17	44	9.15	8.85	.30	3.39
June 13	44	9.86	8.94	.92	10.29
15	44	9.70	9.30	.40	4.30
16	44	9.64	9.04	.60	6.64
Feb. 23	45	9.12	8.63	.49	5.67
24	45	9.26	8.93	.33	3.69
27	45	9.51	9.00	.51	5.67
28	45	9.49	8.99	.50	5.56
Mar. 1	45	9.57	9.08	.49	5.39
2	45	9.21	8.94	.27	3.02
Apr. 11	50	9.29	8.98	.31	3.45
13	50	9.06	8.86	.20	2.26
May 10	50	8.95	8.51	.44	5.17
June 7	50	9.19	8.79	.40	4.55
9	50	9.41	8.58	.83	9.67

TABLE 26.—*Comparison of yield of raw and pasteurized-milk cheese after curing for various lengths of time at Madison, Wis.*—Continued.

Date made.	Time cured after paraffining.	Weight of cured cheese per 100 pounds of milk.		Gain by pasteurization.	
		Pasteurized.	Raw.		
1911.	*Days.*	*Pounds.*	*Pounds.*	*Pounds.*	*Per cent.*
July 3	51	9.05	8.38	0.67	8.00
6	51	9.35	9.21	.14	1.52
June 1	55	9.59	9.49	.10	1.05
2	55	9 33	8.95	.38	4.24
May 29	55	9.52	9.05	.47	5.19
Apr. 25	56	9.62	9.07	.55	6.06
May 2	58	9.32	9.06	.26	2.87
3	58	8.82	8.66	.16	1.84
Apr. 7	56	9.36	8.89	.47	5.28
May 25	62	9.19	8.86	.33	3.72
22	62	9.40	8.74	.66	7.55
26	61	9.16	8.80	.36	4.09
27	61	9 38	8.95	.47	5.25
28	61	9.67	9.35	.32	3.42
19	66	9.66	8.90	.76	8.54
21	66	9.16	8.72	.44	5.05
Apr. 28	65	8.97	8.82	.15	1.70
27	65	8.78	8.10	.68	8.40
24	65	9.01	8.68	.33	3.80
Mar. 10	68	9.10	8.85	25	2.82
21	68	9.15	8.67	.48	5.53
20	68	9.15	8.74	.41	4.69
Apr. 17	72	9.03	8.47	.56	6.61
18	72	8.81	8.34	.47	5.63
Mar. 17	74	9.43	9.28	.15	1.62
16	74	9.72	9.55	.17	1.78
15	74	9.34	9.06	.28	3.09
14	74	9.62	8.99	.63	7.01
14	74	9.37	8.53	.84	9.84
Apr. 13	80	8.76	8.58	.18	2.09
11	80	8.98	8.74	.24	2.74
7	86	9.09	8.68	.41	4.72
5	86	9.33	8.88	.45	5.07
Mar. 9	84	9.24	8.94	.30	3.35
8	84	9.40	9.09	.31	3.41
7	84	9.39	9.13	.26	2.85
3	84	9.24	9.02	.22	2.44
2	87	8.93	8.64	.29	3.35
1	87	8.97	8.85	.12	1.35
Feb. 28	87	9.25	8.71	.54	6.20
27	87	9.28	8.78	.50	5.69
24	87	8.98	8.72	.26	2.98
Mar. 20	98	8.94	8.62	.32	3.71
21	98	8.95	8.44	.51	6.04
22	98	8.91	8.69	.22	2.53
17	104	9.20	9.08	.12	1.32
16	104	9.51	9.35	.16	1.71
15	104	9 12	8.92	.20	2.24
14	104	9.41	8.83	.58	6.57
13	104	9.14	8.46	.68	8.03
9	114	9.02	8.72	.30	3.44
8	114	9.14	8.88	.26	2.93
7	114	9.14	8.93	.21	2.35
3	114	9.06	8.85	.21	2.37
2	117	8.80	8.51	.29	3.41
1	117	8.86	8.75	.11	1.25
Feb. 28	117	9.12	8.63	.49	5.67
27	117	9.15	8.69	.46	5.29
24	117	8.79	8.62	.17	1.97
Average..	....	9.289	8.907	.38	4.22

Cheese stored at New Orleans (lots 1B to 4B).—Fifty-four days' make represented by 54 raw and 54 pasteurized-milk cheeses were shipped to New Orleans in four lots at different times during the season. These cheeses showed an increased yield for the new-process cheese, as compared with the old, in every case. The average figures for each lot are given in Table 27.

TABLE 27.—*Average yield per 100 pounds of milk of raw and pasteurized-milk cheese cured at New Orleans.*

Lot No.	Method.	Number of days' make.	Yield of cheese per 100 pounds of milk.						
			Green.	Paraffined.	Shipped to New Orleans.	Received at New Orleans.	Stored one month.	Stored two months.	Received at Madison.
			Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
1B	Pasteurized	25	10.19	9.69	9.55	9.52	8.85	8.38	8.31
	Raw	25	9.67	9.26	9.16	9.14	8.36	7.85	7.78
	Gain, pounds	....	.52	.43	.39	.38	.49	.53	.53
	Gain, per cent	....	5.37	4.64	4.25	4.16	5.86	6.75	6.81
2B	Pasteurized	9	9.83	9.40	9.37	9.26	8.48	....	8.40
	Raw	9	9.45	9.08	9.05	8.97	8.12	....	8.01
	Gain, pounds	....	.38	.32	.32	.29	.36	....	.39
	Gain, per cent	....	4.02	3.52	3.54	3.23	4.43	....	4.87
3B	Pasteurized	10	10.47	9.99	9.92	9.77	9.29	....	9.17
	Raw	10	9.93	9.54	9.47	9.34	8.69	....	8.55
	Gain, pounds	....	.54	.45	.45	.43	.60	....	.62
	Gain, per cent	....	5.44	4.72	4.75	4.60	6.90	....	7.25
4B	Pasteurized	10	10.38	9.92	9.83	9.78	8.94	....	8.71
	Raw	10	9.69	9.31	9.24	9.19	8.28	....	8.14
	Gain, pounds	....	.69	.61	.59	.59	.66	....	.57
	Gain, per cent	....	7.12	6.55	6.38	6.42	7.97	....	7.00
1-4B	Pasteurized	54	10.22	9.74	9.64	9.57	8.89	....	8.56
	Raw	54	9.68	9.29	9.21	9.16	8.37	....	8.03
	Gain, pounds	....	.54	.45	.43	.41	.52	....	.53
	Gain, per cent	....	5.58	4.84	4.67	4.47	6.21	....	6.60

Among the four lots in Table 27, and in the summary at the bottom of the table, it will be seen that the percentage of gain in yield of pasteurized cheese over raw fell off slowly as the green cheeses were paraffined and shipped, on the average from 5.58 to 4.47 per cent. After these cheeses had been in storage at New Orleans for one month, the raw-milk cheeses were found to have shrunk more than the pasteurized in the majority of cases, raising the percentage of gain in average yield of pasteurized cheese to 6.21 per cent. This was also observed in lot 1B after the second month of storage, and is confirmed both by the weights taken in New Orleans by Mr. Bleecker and by the weights taken at Madison. It was expected that the pasteurized-milk cheese, containing slightly more moisture than the raw-milk cheese, would lose more in weight than the latter when stored at high temperatures. It was surprising to find that the reverse is true in most cases.

The mean daily temperature at New Orleans, as reported by the United States Weather Bureau, varied from 71, the average for April, to 83, the average for June. It is likely that the temperature of the cheese in the warehouse was somewhat higher than the average figures given above, because the warehouse, although well ventilated, was necessarily open more or less during the hot days and closed during the cool nights.

Cheese cured at New Orleans and at Columbus, Ga. (lots 3C and 4C).—Forty cheeses, including 20 pasteurized and 20 raw, were shipped in two shipments for storage in the South through a firm[1] of cheese dealers in Chicago, who weighed the cheese, both before and after storage for one month.

In the first shipment 1 cheese, No. 243-3, was lost in transit, and in the second shipment, 2 cheeses, Nos. 254-1 and 254C1, were damaged so that their weights are not included in the following summary. In the first shipment, according to the Chicago weights, 9 pasteurized-milk cheeses weighed 172½ pounds before storage and 162¼ pounds afterwards. The loss, 10¼ pounds, is 5.94 per cent of the original weight. In the same shipment 10 raw-milk cheeses weighed 189¼ pounds before shipment and 175 pounds afterwards. The loss here, 14¼ pounds, is 7.53 per cent of the original weight.

In the second shipment nine pasteurized-milk cheeses weighed 176½ pounds before and 159¾ pounds after storage. The loss, 16¾ pounds, is 9.49 per cent of the original weight of the cheese. In the same shipment nine raw-milk cheeses weighed 161 pounds before and 144¾ pounds after storage. The loss in this case, 16¼ pounds, is 10.09 per cent of the original weight. In both shipments the raw-milk cheese lost a greater per cent of their weight than the pasteurized-milk cheese. On comparing the individual cheeses in pairs, it was found that in most cases the pasteurized-milk cheese lost less than the raw-milk cheese, although in a few cases the reverse was true.

The weights taken at Madison on the same lots of cheese gave the figures shown in Table 28, agreeing substantially with the results obtained at Chicago:

TABLE 28.—*Average yield per hundred pounds of milk of raw and pasteurized milk cheese cured in the South.*

Lot No.	Method.	Number of days' make.	Weight of cheese per 100 pounds of milk.			
			Green.	Paraffined.	Shipped from Madison.	Received at Madison.
			Pounds.	*Pounds.*	*Pounds.*	*Pounds.*
3C	Pasteurized	9	10.47	9.99	9.92	9.24
	Raw	10	9.93	9.54	9.46	8.68
	Gain, pounds		.54	.45	.46	.56
	Gain, per cent		5.44	4.72	4.86	6.44
4C	Pasteurized	9	10.38	9.92	9.84	8.83
	Raw	9	9.69	9.31	9.24	8.24
	Gain, pounds		.69	.61	.60	.59
	Gain, per cent		7.12	6.55	6.49	7.16

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[1] We are indebted to Messrs. Crosby & Meyers for their kind cooperation in this work.

Cheese cured in a warm room (lots 3D and 4D).—To further test the effect of storage at high temperature 40 cheeses, lots 3D and 4D, were put for 47 days into a warm curing room at Madison where the temperature was held at 75° to 85°.

TABLE 29.—*Average yield per hundred pounds of milk of raw and pasteurized milk cheese cured in warm room.*

Lot No.	Method.	Number of days' make.	Weight of cheese per 100 pounds of milk.			
			Green.	Paraffined.	Put in warm room.	Taken out of warm room.
			Pounds.	*Pounds.*	*Pounds.*	*Pounds.*
3D	Pasteurized	10	10.47	9.99	9.91	9.37
	Raw	9	9.93	9.54	9.46	8.88
	Gain, pounds		.54	.45	.45	.49
	Gain, per cent		5.44	4.72	4.75	5.52
4D	Pasteurized	9	10.38	9.92	9.85	9.33
	Raw	10	9.69	9.31	9.23	8.73
	Gain, pounds		.69	.61	.62	.60
	Gain, per cent		7.12	6.55	6.72	6.87

From these results with eight lots of cheese—1B, 2B, 3B, 4B, 3C, 4C, 3D, and 4D—it can be stated with certainty that pasteurized-milk cheese does not lose more in weight than raw-milk cheese when stored in warm rooms or in the South, after paraffining. On the contrary, the pasteurized-milk cheese lost on the average a smaller percentage of weight in warm storage than the raw-milk cheese. At first this fact seemed inexplicable, but the reason became clearly apparent from inspection of the cheese kept in the warm curing room at Madison. Within a few days after going into the warm room the raw-milk cheese became very greasy on the surface, and the grease running on to the shelves and the floor marked the spot where each cheese stood. The pasteurized-milk cheese, standing alongside of them on the same shelves, did not exude grease, or only very slightly in a few cases, and the difference between the greasy raw-milk cheese and the dry surface of the pasteurized-milk cheese was so marked that there was no difficulty in picking out each kind by the sense of touch alone.

To demonstrate further the difference in this respect, each cheese of the last lot when put into the warm room was placed on a piece of wire gauze in a shallow tin pan, so that the grease running from each cheese could be collected. A very little of the paraffin was scraped from the surface of each cheese by contact with the wire gauze in the bottom of the pan. The total weight of material, practically all paraffin, collected from the 10 pasteurized-milk cheeses weighed 0.13 of a pound, while the material, mostly fat, with a little paraffin and mold, collected from the raw-milk cheeses, weighed 1.92 pounds, which is 1.2 per cent of the weight of the raw cheese when placed in the storeroom.

At present we are unable to explain with certainty why the pasteurized-milk cheese should lose fat less readily when stored at 70° to 80° than the raw-milk cheese. Further study will be made of this phenomenon. The purpose of beginning these studies of losses of weight in warm rooms was to determine whether the increased yield obtained by pasteurization would be offset by increased losses in weight when pasteurized-milk cheese are shipped to the South, and it is now fully demonstrated that the pasteurized-milk cheese stored in the South maintain their advantage as to increased yield.

Cheese placed in cold storage at Waterloo, Wis. (lot 5E).--The losses of weight observed in 35 pasteurized-milk cheeses put into cold storage[1] at 34° at different ages are shown in Table 30. The cheese represent seven days' make during July and August, 1911.

TABLE 30.—*Shrinkage of pasteurized-milk cheese in cold storage.*

Date made.	Cheese No.	Weight, green.	When paraffined.		When put into cold storage.		When taken out of cold storage.		Total shrinkage.	
			Age.	Weight.	Age.	Weight.	Age.	Weight.		
1911.		*Pounds.*	*Days.*	*Pounds.*	*Days.*	*Pounds.*	*Days.*	*Pounds.*	*Pounds.*	*Per cent.*
July 19	264-1	20.60	9	19.60	(2)	(2)	100	18.15	2.45	11.89
19	264-2	21.11	1	20.70	1	20.70	100	20.38	.73	3.45
19	264-3	20.10	7	19.21	7	19.21	100	19.15	.95	4.72
19	264-4	21.07	9	20.05	14	20.04	100	19.85	1.22	5.79
19	264-5	19.89	9	18.90	28	18.70	100	18.28	1.61	8.09
19	264-6	20.45	9	19.44	41	18.95	100	18.65	1.80	8.80
21	265-1	22.49	8	21.60	(2)	(2)	99	20.10	2.39	10.62
21	265-2	17.98	1	17.58	1	17.58	99	17.45	.53	2.94
21	265-3	20.21	7	19.35	7	19.35	99	19.25	.96	4.75
21	265-4	18.86	8	17.98	14	17.92	99	17.75	1.11	5.89
21	265-5	19.58	8	18.68	28	18.42	99	18.05	1.53	7.81
21	265-6	19.25	8	18.40	28	18.13	99	17.68	1.57	8.16
21	265-7	19.75	8	18.86	40	18.36	99	18.10	1.65	8.35
25	267-1	20.82	11	19.86	(2)	(2)	95	18.50	2.32	11.14
25	267-2	20.29	1	19.95	1	19.95	95	19.80	.49	2.41
25	267-3	19.97	7	19.11	7	19.11	95	18.90	1.07	5.35
25	267-4	21.55	11	20.58	14	20.58	95	20.38	1.17	5.43
25	267-5	20.23	11	19.25	29	18.98	95	18.58	1.65	8.15
25	267-6	22.20	11	21.31	43	20.62	95	20.25	1.95	8.78
27	269-1	18.70	9	17.80	(2)	(2)	93	16.45	2.25	12.03
27	269-2	19.88	1	19.45	1	19.45	93	19.20	.68	3.42
27	269-3	19.85	7	19.01	7	19.01	93	18.95	.90	4.53
27	269-4	20.87	9	19.92	14	19.92	93	19.55	1.32	6.32
27	269-5	18.80	9	17.91	27	17.60	93	17.22	1.58	8.40
27	269-6	20.22	9	19.22	41	18.61	93	18.25	1.97	9.74
Aug. 1	272-1	21.91	11	20.65	(2)	(2)	89	19.00	2.91	13.28
1	272-2	19.78	1	19.30	1	19.30	89	19.05	.73	3.69
1	272-3	19.40	7	18.55	7	18.55	89	18.22	1.18	6.08
1	272-4	21.82	11	20.55	14	20.55	89	20.25	1.57	7.19
1	272-5	21.80	11	20.57	29	20.26	89	19.90	1.90	8.71
1	272-6	21.75	11	20.50	46	19.75	89	19.50	2.25	10.34
1	276-1	19.90	11	18.63	(2)	(2)	81	17.20	2.70	13.56
8	276-2	20.42	1	19.98	1	19.98	81	19.60	.82	4.01
8	276-3	20.44	7	19.50	7	19.50	81	19.30	1.14	5.57
8	276-4	19.90	11	18.66	15	18.63	81	18.40	1.50	7.53
8	276-5	19.70	11	18.45	28	18.21	81	17.75	1.95	9.89
22	283-1	20.10	......	....	(2)	(2)	67	18.10	2.00	9.95
22	283-2	19.90	1	19.50	1	19.50	67	19.38	.52	2.61
22	283-3	19.68	8	18.81	8	18.81	67	18.75	.93	4.72
22	283-4	18.80	11	17.90	15	17.70	67	17.40	1.40	7.44
22	283-5	19.84	11	18.84	29	18.62	67	18.45	1.39	7.00
22	283-6	18.65	11	17.62	42	(2)	67	16.80	1.85	9.92

SUMMARY.

No. of cheese................	7	7	7	7	6	7
Age when stored............	1 day.	1 week.	2 weeks.	4 weeks.	6 weeks.	In cellar.
Average total shrinkage, per cent....................	3.22	5.10	6.51	8.29	9.29	11.78

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[1] In warehouse at Waterloo, Wis., by courtesy of the Roach & Seeber Co.

[2] Cured in cellar.

Although the seven cheeses put into storage at the age of 1 day showed an average of only 3.22 per cent shrinkage after three months, yet they were not well broken down and required further curing at 60° to 70° to get rid of their curdy, lumpy texture. The cheese paraffined and stored when 1 week old showed an average total shrinkage of 5.10 per cent, and these were found to be thoroughly broken down when taken out of cold storage. This series appears to indicate that the quality of pasteurized-milk cheese is not damaged by placing in cold storage at the age of 1 week, while the shrinkage (5.10 per cent) is about half that of the duplicate cheese, cured in the cellar at Madison (11.78 per cent), as shown at the bottom of the table.

THE CAUSES OF THE INCREASED YIELD FROM PASTEURIZED MILK.

THE LOSSES OF FAT FROM VAT AND PRESS.

The increased yield of green cheese from pasteurized milk, amounting to over 5 per cent (Table 20), is due partly to the fact that about half of the fat lost in the whey and drippings by the old process is retained in the cheese by the new process of making. Also it is found that a little more moisture can safely be incorporated in the new-process cheese without danger of spoiling it, but on the contrary giving it a moist, fat appearance which consumers generally like. The loss of fat in the whey is caused partly by the passage of the curd knives through the curd in cutting, at which time a considerable proportion of fat is brushed away from the surface of the curd cubes. During the stirring and heating some further fat globules are lost from the curd cubes, and still further losses occur after milling and during pressing. In the new process of making cheese from pasteurized milk the curd is so firm and elastic (not brittle) at the time of cutting that the loss of fat in the whey averages only about one-half that observed in cheese making by the ordinary process.

The average fat content of whey from good clean milk is stated to be 0.30 per cent and from average cheese factory milk 0.36 per cent.[1] On a great many days during the past two and one-half years the milk supply in the receiving vat has been divided and one half made up by the regular methods and the other half by the new method. The quality and composition of the milk was thus the same in both vats. On the 24 days listed in Table 31 the average fat content of the whey from the regular vats was 0.25 per cent and from the pasteurized-milk vats was 0.159 per cent.

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[1] Van Slyke and Publow, loc. cit., pp. 189, 190.

TABLE 31.—*Comparison of the percentage of fat in whey by new method and by regular method of cheese making.*

Date.	Fat in milk.	New method.		Regular method.	
		Weight of milk used.	Fat in whey when drawn.	Weight of milk used.	Fat in whey when drawn.
1911.	*Per ct.*	*Pounds.*	*Per cent.*	*Pounds.*	*Per cent.*
Aug. 29	4.1	294½	0.14	290	0.17
30	3.6	344	.14	344	.26
Sept. 1	....	322	.15	320	.20
5	4.0	291½	.17	292	.28
6	3.6	276	.19	276	.32
7	4.1	286½	.18	286½	.32
8	....	292	.16	795	.26
1909.					
July 21	4.0	200	.15	200	.21
22	3.9	200	.12	200	.20
23	4.0	200	.15	200	.19
24	4.0	200	.12	200	.22
Aug. 12	3.7	200	.16	200	.26
1908.					
July 18	4.1	200	.12	200	.22
Oct. 1	4.7	200	.20	200	.30
2	4.5	200	.18	200	.29
7	4.4	200	.14	200	.19
8	4.0	200	.15	200	.25
Sept. 1	4.3	200	.17	200	.32
2	4.2	200	.18	200	.30
14	4.2	200	.18	200	.24
16	4.0	200	.13	200	.27
17	4.4	200	.19	200	.29
18	4.4	200	.18	200	.25
19	4.2	200	.17	200	.23
Average..	....	....	.159	....	.25

In these cases the small amount of milk handled in each vat permitted hand stirring, and neither the rake nor the agitator was used. By this means the whey fat of the regular-process vats was kept at a lower figure, perhaps, than could have been done with large vats, as handled in a commercial factory using the regular process.

On 22 days, using 1,200 to 2,000 pounds of pasteurized milk in each vat, the percentage of fat in the whey at the time of drawing the whey averaged 0.17 per cent, as shown in the following table. In these cases the vats were stirred with an agitator.

TABLE 32.—*Fat content of whey from pasteurized-milk cheese.*

Date.	Fat in whey two hours after cutting.	Weight of milk handled.	Weight of cheese.
1910.	*Per cent.*	*Pounds.*	*Pounds.*
May 25	0.14	1,234	139
26	.16	1,322	153
27	.18	1,337	144
June 1	.17	1,578	166
6	.12	2,061	226
7	.15	1,427	159
8	.14	1,431	158
9	.18	1,360	147
10	.17	1,448	162

Table 32.—*Fat content of whey from pasteurized-milk cheese*—Continued.

Date.	Fat in whey two hours after cutting.	Weight of milk handled.	Weight of cheese.
1910.	*Per cent.*	*Pounds.*	*Pounds.*
June 14	0.20	1,398	148
16	.20	1,165	126
17	.20	1,320	152
20	.20	1,588	170
21	.23	1,292	144
22	.14	1,347	144
23	.16	1,329	139
24	.18	1,337	139
28	.24	1,277	130
29	.14	1,210	130
30	.17	1,243	131
July 5	.18	1,242	125
6	.14	1,229	134
Average..	.17	....	....

Most of the loss of fat from curd occurs at the moment of cutting, as shown by the figures in Table 33. On 23 days samples of whey were taken daily from the vat as soon after cutting as it was possible to obtain any clear whey—that is, in four to six minutes. The fat content of this whey, sampled five minutes after cutting, tested 0.47 per cent on the average of 23 days, while the average test of samples taken from the same vats two hours after cutting was 0.16 per cent. The average weight of milk handled daily in the vat was 1,110 pounds, and the average fat test of the milk was 4 per cent.

Table 33.—*Fat content of whey at time of cutting curd and 2 hours later.*

Date.	Time after cutting curd.		Weight of milk handled.	Weight of cheese.
	4 to 6 minutes.	2 hours.		
1910.	*% fat.*	*% fat.*	*Pounds.*	*Pounds.*
Apr. 8	0.45	0.16	1,011	102
12	.46	.19	1,011	104
13	.40	.15	967	98
14	.40	.14	1,045	108
15	.50	.12	1,001	100
18	.35	.13	993	103
19	.55	.22	906	97
22	.40	.16	755	77
25	.42	.19	1,065	117
26	.52	.17	940	103
27	.52	.16	1,004	109
28	.57	.15	972	102
29	.45	.14	796	102
May 3	.65	.16	1,041	122
4	.67	.16	1,055	118
5	.52	.17	1,119	129
6	.50	.20	917	97
10	.52	.16	1,288	141
11	.50	.15	1,285	138
18	.35	.15	1,239	137
19	.40	.14	1,186	130
23	.25	.12	2,477	268
24	.45	.19	1,454	154
Average..	.47	.16	1,110	119.8

The reason for the decrease in percentage of fat in whey at two hours after cutting is that there was little fat lost from the curd during the time the whey was being expelled, so that the fat lost from the curd cubes at the moment of cutting was diluted about 0.47 divided by 0.16 = 3 times by the water expelled from the curd during the two-hour period.

Losses of fat after drawing the whey.—On several days the whey drippings from the pasteurized-milk curd, from the time the curd was all on the rack up to the time when it was taken from the press, were collected, weighed, and tested for fat. From this could be calculated the weight of fat lost in the drippings, as shown in Tables 34, 35, and 36:

TABLE 34.—*Loss of fat in drippings in 2 hours and 50 minutes—From dipping to hooping—Pasteurized-milk curd.*

Date.	Total weight of drippings collected.	Fat in drippings.		Weight of cheese made.
1910.	*Pounds.*	*Per cent.*	*Pound.*	*Pounds.*
Apr. 12	29	0.27	0.078	104
13	28	.27	.075	98
14	31	.30	.093	108
15	33	.25	.082	100
18	21	.20	.042	103
19	26	.10	.026	97
20	20	.15	.030	91½
21	25	.18	.045	95½
22	21	.12	.025	77
25	24	.20	.048	117
Total.....	258	....	.544	991

TABLE 35.—*Losses of fat in drippings before pressing pasteurized-milk curds.*

Date.	Drippings in 1⅓ hours—dipping to milling.			Drippings in 1⅓ hours—milling to hooping.			Weight of cheese.
	Weight.	Fat content.		Weight.	Fat content.		
1910.	*Pounds.*	*Per cent.*	*Pound.*	*Pounds.*	*Per cent.*	*Pound.*	*Pounds.*
Apr. 27	35	0.02	0.007	5.0	1.8	0.090	109
28	24	.05	.012	5.0	1.8	.090	102
29	24	.02	.050	3.0	1.8	.054	84
May 3	25	.08	.020	2.5	1.8	.045	122½
4	25	.05	.012	1.5	.6	.009	118
5	29	.07	.020	3.0	1.7	.051	129
10	26	.07	.018	4.0	1.2	.048	141
11	24	.07	.017	3.0	1.6	.048	137½
13	25	.16	.040	3.0	2.0	.060	103
18	24	.06	.014	4.5	2.0	.090	137
19	25	.05	.012	5.0	1.4	.070	125
23	38	.04	.015	9.0	1.5	.135	268
24	26	.14	.036	5.0	2.0	.100	162
Total.......	350	....	.273	53.5	....	.890	1,738
Calculated for 10 lbs. of cheese...	2.01	....	.00157	.3078	....	.00512	....

TABLE 36.—*Loss of fat in drippings from pasteurized-milk cheese in press.*

Date.	Total weight of cheese pressed.	Total weight of drippings.	Fat in drippings.	
1910.	*Pounds.*	*Pounds.*	*Per cent.*	*Pounds.*
May 16-20	808	24	3.85	0.92
23-27	873	32	3.2	1.02
Total.......	1,681	56	....	1.94
Calculated for 10 lbs. of cheese ..	....	.33	....	.0115

Summary of losses of fat by the new method of cheese making.—The total loss of fat from cheese in the new process is about 1.6 per cent of the weight of the cheese, as shown in the following summary of the preceding tables:

TABLE 37.—*Total losses of fat in making 10 pounds of cheese from pasteurized milk.*

Period.	Total. weight.	Fat content.		Loss of fat from cheese.
	Pounds.	*Per cent.*	*Pound.*	*Per cent.*
Whey when drawn..................	87.4	0.16	0.1400	1.400
Drippings from curd before milling..................	2.01	.08	.0016	.016
Drippings from curd in vat after milling..................	.31	1.66	.0051	.051
Drippings from press..................	.33	3.46	.115	.115
Total..................	90.05	....	.1583	1.583

The average total loss of fat from 100 pounds of milk handled by the new process of cheese making is seen to be on the average 0.158 pounds of fat, or a little less than 4 per cent of the total fat content of milk containing 4 per cent fat. The loss of fat from 100 pounds of milk in ordinary cheese making under average factory conditions has been found to amount to 0.33 of a pound of fat, or 0.36 per cent of fat in the whey, or 9 per cent of the total fat content of the milk.[1]

It will be seen from these figures that the loss of fat is reduced to less than one-half by the new process of cheese making. It might be expected from this statement that each day's make of pasteurized-milk cheese tested by the Babcock test would show a higher percentage of fat than the same day's raw-milk cheese. In Table 38, however, it is seen that in 15 cases out of 21 the pasteurized-milk cheese tested lower in fat (0.65 per cent lower on the average) than the raw-milk cheese.

THE INCREASED MOISTURE CONTENT OF PASTEURIZED-MILK CHEESE.

This is due to the fact that there is an increased content of moisture as well as of fat in the new-process cheese, and in most cases the increase of moisture is greater than the increase of fat. On this account the moisture content of pasteurized cheese listed in the table below is greater than that of the raw-milk cheese in 29 cases out of 33, and the average percentage was 1.68 greater.

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[1] Van Slyke and Publow, loc. cit., p. 189.

The cheeses listed in the table were the same as those in Table 26, and the testing for fat and moisture was done immediately after the last weights had been taken for the determination of yield and shrinkage. The samples of cheese weighed into the Babcock test bottles were rapidly dissolved in a mixture of hot water and sulphuric acid, as suggested by one of us in a previous paper.[1]

Table 38.—*Comparison of the fat and moisture content of raw and pasteurized milk cheese cured at Madison.*

Date.	Moisture content of cheese.				Fat content of cheese.			
	Pasteurized.	Raw.	Difference.		Pasteurized.	Raw.	Difference.	
1911.	*Per ct.*	*Per ct.*	+*Per ct.*	−*Per ct.*	*Per ct.*	*Per ct.*	−*Per ct.*	+*Per ct.*
Feb. 24	30.50	30.15	0.35		38.86	39.10	0.24	
27	33.55	30.15	3.40					
28	32.52	30.05	2.47					
Mar. 1	32.55	31.25	1.30					
2	31.60	30.75	.85					
3	31.05	31.47		0.42				
7	31.90	29.75	2.15		37.44	38.16	.72	
8	32.37	30.17	2.20		37.99	38.16	.17	
9	32.77	31.32	1.45		38.61	38.04		0 57
10	32.45	31.45	1.00					
13	33.15	30.00	3.15					
14	33.51	31.95	1.56					
15	31.62	30.90	.72		38.28	38.36	.08	
16	33.40	30.87	2.53		38.61	38.39		.22
17	34.15	33.22	.93		38.01	37.97		.04
20	32.72	31.58	1.14					
21	32.90	30.10	2.80					
22	34.00	32.20	1.80					
Apr. 5	34.10	32.25	1.85		36.93	37.09	.16	
7	34.52	31.92	2.60		36.56	36.85	.29	
11	32.90	31.97	.93					
13	31.78	30.17	1.61		36.84	37.02	.18	
17	33.47	31.55	1.92		36.81	37.94	1.13	
18	33.55	30.15	3.40		38.22	39.95	1.73	
24	32.28	32.68		.40	39.18	38.86		.32
27	31.80	32.70		.90	38.64	38.66	.02	
28	34.17	33.22	.95		37.93	39.08	1.15	
May 2	32.63	31.25	1.38		39.55	40.68	1.13	
3	31.02	30.87	.15		40.68	41.43	.75	
8	32.87	31.05	1.82		37.97	39.06	1.09	
10	31.65	30.45	1.20		39.28	39.27		.01
15	33.47	32.25	1.22		37.97	38.66	.69	
17	31.87	32.58		.71	38.10	37.67		.43
Average..	32.69	31.28	1.68	.61	38.21	38.59	.65	.26

The combined effect upon the percentage composition of cheese caused by increasing both the fat and moisture content is shown in the following example:

Ten pounds of raw-milk cheese of the same average percentage composition as in Table 38, as shown at I, below, would contain the weights of fat, moisture, and casein, etc., shown at II. If by pasteurization the fat content of the cheese is increased about 4 per cent of itself, and the moisture content is increased about 12½ per cent of itself, there will be obtained 10.54 pounds of pasteurized-milk cheese as shown at III instead of 10 pounds of raw-milk cheese, a theoretical gain of 5.4 per cent in the yield of cheese. (The actual gain shown in Table 20 was 5.37 per cent.) The percentage composition of this pasteurized cheese will be as shown at IV, which agrees closely with the average composition of the pasteurized-milk cheese shown at the bottom of Table 38.

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[1] Sammis, J. L. The determination of fat in cheese by the Babcock test. Journal of Industrial and Engineering Chemistry, vol. 1, no. 8, p. 604. Easton, Pa., Aug., 1909.

	I.	II.		III.	IV.
Fat......	38.59 per cent.	3.859 pounds+	0.154 pounds=	4.013 pounds.	38.07 per cent·
Moisture..	31.28 per cent.	3.128 pounds+	0.391 pounds=	3.519 pounds.	33.37 per cent.
Casein,etc.	30.13 per cent.	3.013 pounds+	.... pounds=	3.013 pounds.	28.57 per cent.
	100.00 per cent.	10.000 pounds.		10.545 pounds.	100.00 per cent.

The increased moisture content of pasteurized-milk cheese made by this process is due to the effect of pasteurization on the properties of curd, as stated on page 25.

THE QUALITY OF PASTEURIZED-MILK CHEESE.

SCORES AND CRITICISMS OF PASTEURIZED AND RAW MILK CHEESE.

The milk supply used at Madison is no better than the average cheese-factory milk. Sunday's milk is delivered on Monday throughout the year and is therefore inferior to that of the other days. Cheese from every day's make during the season was scored by two judges, Mr. U. S. Baer, assistant dairy and food commissioner of the State of Wisconsin, and Mr. A. T. Bruhn, junior dairyman, United States Department of Agriculture, who during the past year have scored the cheese sent to the monthly scoring exhibition, conducted by the Wisconsin Experiment Station. The judges worked independently and pinned their scoresheets to each cheese without knowing even the numbers of the cheese, which were turned toward the wall. Their scores show close agreement with each other in most cases and leave no doubt as to the relative quality of the cheese scored. After finishing about 20 of the cheeses, they turned them around and added the cheese numbers to the sheets. In general, a score of 92 or above indicates that the cheese is of good quality and salable at full market price. A cheese scored below 92 is likely to be cut in price in a dull market. Tables 39 to 46 show the scores of both judges as well as the average scores, which latter are used in the discussion. Raw-milk cheese is in all cases indicated by the letter C attached to the serial number.

CHEESE CURED AT MADISON AT NORMAL TEMPERATURE.

Lots 1A, 2A, 3A, and 4A.—These lots include 53 pairs of cheese cured in the cellar at Madison. The temperature of the curing room showed daily about 3° to 5° difference between maximum and minimum and ranged from 60° to 73° from February to July, 1911. By opening the windows at night only, it was kept at 60° to 70° from July to October.

The scores of the 53 pairs of cheese are as shown in Table 39. The average score of all the pasteurized-milk cheese is 92.75 and of the raw-milk cheese 89.09.

TABLE 39.—*Scores of 53 pairs of raw and pasteurized cheese (lots 1A, 2A, 3A, and 4A) cured at Madison.*

LOTS 1A AND 2A, SCORED JULY 17, 1911.

Temperature of curing room 8 a. m.	Date made.		Cheese No.[1]	Scored by U. S. Baer.			Scored by A. T. Bruhn.			Average.		
				Flavor.	Texture.	Total.	Flavor.	Texture.	Total.	Flavor.	Texture.	Total.
°*F.*	1911.											
....	Feb.	24	172	41.0	26.0	92.0	40.0	26.5	91.5	40.50	26.25	91.75
....		24	172C	37.0	27.0	89.0	38.0	27.0	90.0	37.50	27.00	89.50
....		27	173	43.0	28.5	96.5	42.5	28.0	95.5	42.75	28.25	96.00
....		27	173C	38.0	27.0	90.0	40.0	27.0	92.0	39.00	27.00	91.00
....		28	174	41.0	27.0	93.0	41.0	27.5	93.5	41.00	27.25	93.25
....		28	174C	39.0	26.0	90.0	39.0	26.5	90.5	39.00	26.25	90.25
....	Mar.	1	175	41.0	27.0	93.0	40.0	26.0	91.0	40.50	26.50	92.00
....		1	175C	40.0	26.0	91.0	40.0	26.5	91.5	40.00	26.25	91.25
....		2	176	40.0	28.0	93.0	41.0	27.0	93.0	40.50	27.50	93.00
....		2	176C	37.0	27.0	89.0	39.0	27.0	91.0	38.00	27.00	90.00
....		3	177	40.0	27.0	92.0	40.0	26.5	91.5	40.00	26.75	91.75
....		3	177C	38.0	26.0	89.0	38.0	26.0	89.0	38.00	26.00	89.00
....		7	178	40.0	26.0	91.0	40.0	27.0	92.0	40.00	26.50	91.50
....		7	178C	38.0	27.0	90.0	39.0	27.0	91.0	38.50	27.00	90.50
....		8	179	40.0	27.0	92.0	41.0	27.5	93.5	40.50	27.25	92.75
....		8	179C	35.0	26.0	86.0	38.0	26.0	89.0	36.50	26.00	87.50
....		9	180	41.0	26.0	92.0	41.0	27.0	93.0	41.00	26.50	92.50
....		9	180C	39.0	26.0	90.0	40.5	26.5	92.0	39.75	26.25	91.00
....		10	181	41.0	26.0	92.0	42.0	27.0	94.0	41.50	26.50	93.00
....		10	181C	38.0	27.0	90.0	39.0	26.5	90.5	38.50	26.75	90.25
....		13	182	40.0	27.0	92.0	41.0	27.0	93.0	40.50	27.00	92.50
....		13	182C	41.0	26.0	92.0	40.0	27.0	92.0	40.50	26.50	92.00
....		14	183	40.0	26.0	91.0	40.0	26.5	91.5	40.00	26.25	91.25
....		14	183C	40.0	27.0	92.0	40.0	26.5	91.5	40.00	26.75	91.75
....		15	184	40.0	26.0	91.0	41.0	27.0	93.0	40.50	26.50	92.00
....		15	184C	40.0	27.0	92.0	41.5	27.0	93.5	40.75	27.00	92.75
60		16	185	40.0	26.0	91.0	41.5	27.0	93.5	40.75	26.50	92.25
....		16	185C	35.0	26.0	86.0	41.0	27.0	93.0	38.00	26.50	89.50
62		17	186	42.0	28.0	95.0	41.0	26.5	92.5	41.50	27.25	93.75
....		17	186C	41.0	28.0	94.0	41.0	27.0	93.0	41.00	27.50	93.50
63		20	187	43.0	27.0	95.0	41.0	26.0	92.0	42.00	26.50	93.50
....		20	187C	35.0	25.0	85.0	39.0	26.5	90.5	37.00	25.75	87.75
66		21	188	43.0	28.0	96.0	41.0	27.0	93.0	42.00	27.50	94.50
....		21	188C	38.0	26.0	89.0	40.0	27.0	92.0	39.00	26.50	90.50
66		22	189	43.0	27.0	95.0	42.0	28.0	95.0	42.50	27.50	95.00
....		22	189C	39.0	27.0	91.0	40.0	27.0	92.0	39.50	27.00	91.50
62	Apr.	5	198	43.0	27.0	95.0	42.0	28.0	95.0	42.50	27.50	95.00
....		5	198C	41.0	27.0	93.0	41.5	28.0	94.5	41.25	27.50	93.75
....		7	200	42.0	27.0	94.0	42.0	27.0	94.0	42.00	27.00	94.00
64		7	200C	35.0	25.0	85.0	40.0	26.0	91.0	37.50	25.50	88.00
....		11	202	42.0	26.0	93.0	42.5	27.0	94.5	42.25	26.50	93.75
....		11	202C	39.0	26.0	90.0	40.0	27.0	92.0	39.50	26.50	91.00
....		13	204	41.0	27.0	93.0	42.0	28.0	95.0	41.50	27.50	94.00
....		13	204C	39.0	26.0	90.0	40.0	27.0	92.0	39.50	26.50	91.00
....		17	206	41.0	27.0	93.0	41.0	27.0	93.0	41.00	27.00	93.00
....		17	206C	40.0	25.0	90.0	38.0	25.0	87.0	39.00	25.00	88.50
....		18	207	43.0	26.0	94.0	41.5	27.0	93.5	42.25	26.50	93.75
....		18	207C	42.0	25.0	92.0	40.0	25.0	90.0	41.00	25.00	91.00
....		24	211	43.0	26.0	94.0	42.0	27.0	94.0	42.50	26.50	94.00
....		24	211C	39.0	25.0	89.0	39.0	27.0	91.0	39.00	26.00	90.00
....		27	214	40.0	25.0	90.0	42.5	27.0	94.5	41.25	26.00	92.25
....		27	214C	37.0	24.0	86.0	37.0	26.0	88.0	37.00	25.00	87.00
....		28	215	42.0	27.0	94.0	42.0	27.0	94.0	42.00	27.00	94.00
60		28	215C	37.0	25.0	87.0	38.0	26.0	89.0	37.50	25.50	88.00
....	May	2	216	41.0	26.0	92.0	40.5	26.0	91.5	40.75	26.00	91.75
58		2	216C	37.0	25.0	87.0	38.0	26.0	89.0	37.50	25.50	88.00
....		3	217	42.0	28.0	95.0	41.5	27.0	93.5	41.76	27.50	94.25
62		3	217C	37.0	25.0	87.0	40.0	26.0	91.0	38.50	25.50	89.00
....		8	220	41.0	27.0	93.0	42.0	27.0	94.0	41.50	27.00	93.50
62		8	220C	34.0	25.0	84.0	39.0	25.0	89.0	36.50	25.00	86.50
....		10	222	40.0	25.0	90.0	40.0	27.0	92.0	40.00	26.00	91.00
63		10	222C	37.0	25.0	87.0	40.0	26.0	91.0	38.50	25.50	89.00
....		15	225	40.0	26.0	91.0	42.0	28.0	95.0	41.00	27.00	93.00
64		15	225C	38.0	26.0	89.0	39.0	27.0	91.0	38.50	26.50	90.00
....		17	227	41.0	26.0	92.0	41.0	27.0	93.0	41.00	26.50	92.50
67		17	227C	35.0	24.0	84.0	37.0	25.0	87.0	36.00	24.50	85.50

"C" in this column indicates raw-milk cheese.

TABLE 39.—*Scores of 53 pairs of raw and pasteurized cheese (lots 1A, 2A, 3A, and 4A) cured at Madison*—Continued.

LOT 3A, SCORED AUGUST 14, 1911.

Temperature of curing room 8 a. m.	Date made.		Cheese No.[1]	Scored by U. S. Baer.			Scored by A. T. Bruhn.			Average.		
				Flavor.	Texture.	Total.	Flavor.	Texture.	Total.	Flavor.	Texture.	Total.
°*F.*	1911.											
67	May	22	230	43.0	27.0	95.0	41.5	26.5	93.0	42.25	26.75	94.00
....		22	230C	40.0	26.0	91.0	37.0	25.0	87.0	38.50	25.50	89.00
66		25	233	41.0	25.0	91.0	41.0	26.0	92.0	41.00	25.50	91.50
....		25	233C	38.0	25.0	88.0	36.0	25.0	86.0	37.00	25.00	87.00
....		29	234	42.0	27.0	94.0	42.0	27.0	94.0	42.00	27.00	94.00
....		29	234C	39.0	25.0	89.0	37.0	25.0	87.0	38.00	25.00	88.00
....	June	1	237	42.0	27.0	94.0	41.0	26.5	92.5	41.50	26.75	93.25
66		1	237C	35.0	25.0	85.0	38.0	26.0	89.0	36.50	25.00	87.00
....		2	238	40.0	26.0	91.0	41.0	26.5	92.5	40.50	26.25	91.75
66		2	238C	37.0	26.0	88.0	37.0	25.5	87.5	37.00	25.75	87.75
....		7	240	40.0	27.0	92.0	41.0	26.0	92.0	40.50	26.50	92.00
66		7	240C	33.0	25.0	83.0	37.0	26.0	88.0	35.00	25.50	85.50
....		9	242	39.0	27.0	91.0	41.5	26.0	92.5	40.25	26.50	91.75
70		9	242C	39.0	26.0	90.0	38.0	26.0	89.0	38.50	26.00	89.50
....		13	243	40.0	27.0	92.0	41.0	26.0	92.0	40.50	26.50	92.00
68		13	243C	38.0	25.0	88.0	38.0	25.0	88.0	38.00	25.00	88.00
....		15	245	41.0	27.0	93.0	41.5	27.0	93.5	41.25	27.00	93.25
66		15	245C	37.0	26.0	88.0	40.0	26.0	91.0	23.50	26.00	89.50
....		16	246	40.0	27.0	92.0	40.0	26.0	91.0	40.00	26.50	91.50
66		16	246C	40.0	26.0	91.0	39.0	27.0	91.0	39.50	26.50	91.00

LOT 4A, SCORED SEPTEMBER 18, 1911.

Temperature of curing room 8 a. m.	Date made.		Cheese No.[1]	Scored by U. S. Baer.			Scored by A. T. Bruhn.			Average.		
				Flavor.	Texture.	Total.	Flavor.	Texture.	Total.	Flavor.	Texture.	Total.
68	June	19	248	42.0	27.0	94.0	42.0	27.0	94.0	42.00	27.00	94.00
....		19	248C	40.5	26.0	91.5	40.0	26.5	91.5	40.25	26.25	91.50
68		21	250	40.0	26.0	91.0	41.0	26.5	92.5	40.50	26.25	91.75
....		21	250C	37.0	25.0	87.0	38.0	25.0	88.0	37.50	25.00	87.50
70		26	253	37.0	25.0	87.0	39.0	25.0	89.0	38.00	25.00	88.00
....		26	253C	35.0	25.0	85.0	35.0	26.0	86.0	35.00	25.50	85.50
70		27	254	41.0	27.0	93.0	41.0	27.0	93.0	41.00	27.00	93.00
....		27	254C	37.0	26.0	88.0	37.0	26.0	88.0	37.00	26.00	88.00
70		28	255	41.0	27.0	93.0	41.0	27.0	93.0	41.00	27.00	93.00
....		28	255C	35.0	25.0	85.0	37.0	25.5	87.5	36.00	25.25	86.25
72	July	3	258	40.0	27.0	92.0	40.5	26.5	92.0	40.25	26.75	92.00
....		3	258C	35.0	25.0	85.0	35.0	25.0	85.0	35.00	25.00	85.00
72		8	260	41.0	27.0	93.0	41.0	26.5	92.5	41.00	26.75	92.75
....		8	260C	37.0	25.0	87.0	36.0	25.0	86.0	36.50	25.00	86.50
73		10	261	40.0	25.0	90.0	39.5	26.0	90.5	39.75	25.50	90.25
....		10	261C	38.0	27.0	90.0	38.0	27.0	90.0	38.00	27.00	90.00
73		11	262	41.0	27.0	93.0	41.0	26.5	92.5	41.00	26.75	92.75
....		11	262C	37.0	26.0	88.0	37.0	25.5	87.5	37.00	25.75	87.75
72		12	263	40.0	26.0	91.0	40.0	26.0	91.0	40.00	26.00	91.00
....		12	263C	35.0	26.0	86.0	35.0	26.0	86.0	35.00	26.00	86.00

[1] "C" in this column indicates raw-milk cheese.

In 51 cases out of the 53 in the table the pasteurized-milk cheese received a higher average total score than the raw-milk cheese; but in two cases the raw-milk cheese scored one-fourth to one-half a point higher (Nos. 183 and 184). In the 51 cases just mentioned the differences in total score between pasteurized and raw milk cheese ranged from one-fourth of a point to 7 points and averaged 3.82 points. In four-fifths of these cases the difference in the score was over 2 points. In 49 of the 53 raw-milk cheeses the average score was below 92, while 39 of the 53 pasteurized-milk cheeses scored 92 or above. The distribution of the scores in each case is most clearly shown in figure 3.

It can readily be seen from figure 3 that 94 per cent (50 out of 53) of the pasteurized cheese scores lie between 91 and 95, a range of 4 points, while the same proportion (94 per cent) of the raw-milk cheese scores are quite uniformly distributed between 85 and 92, a range of 7 points.

The variation in quality of product from day to day is thus reduced nearly one-half by the new process. In scoring all of these cheeses the color and make-up were always marked perfect, and the cheeses were marked off only on flavor and texture. It is of interest therefore to consider the flavor and texture scores separately, in addition to the discussion of total scores given above.

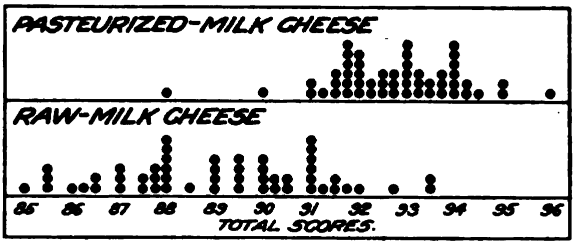

FIG. 3.—Distribution of total scores of pasteurized and raw milk cheese.

The average flavor score for all of the pasteurized cheese is 41.05 and for the raw-milk cheese 38.13. In 50 cases out of 53 the pasteurized-milk cheese has a higher average flavor score than the raw, in 2 cases the scores are equal, and in 1 case the pasteurized cheese is one-fourth point less than the raw.

In the 50 cases just mentioned the difference in the flavor score between the two makes of cheese ranged from 0.50 to 5.50 points, averaging 3.1 points. The difference was equal to or greater than 1.25 points in 47 out of the 50 cases, showing that the improvement in flavor through pasteurization was not only unquestionable, but also consistent. In 51 out of the 53 cases the pasteurized-milk cheese scored 40 or above for flavor, while 45 out of the 53 raw-milk cheese scored below 40 for flavor.

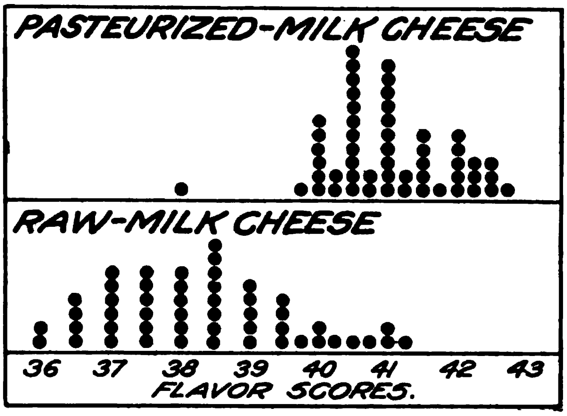

FIG. 4.—Distribution of flavor scores of pasteurized and raw milk cheese.

Figure 4 shows that 94 per cent (50 out of 53) of the pasteurized cheese flavor scores lie between 40 and 42½, a range of 2½ points; while the raw-milk cheese flavor scores are quite evenly distributed over a range of 5 points (from 35 to 40 or 41). The range of variation is thus twice as great in the raw as it is in the pasteurized, showing that the daily variation of flavor is reduced about one-half by the new process.

The average texture scores show also some advantage for the new-process cheese. The average texture score on all of the pasteurized-milk cheese was 26.70, and on the raw-milk cheese 25.96.

In 40 cases out of 53 the pasteurized cheese scored higher than the raw, in five cases the scores were equal, and in 8 cases the pasteurized cheese scored 0.25 to 1.5 points (average 0.59 point) lower than the raw. Among the 40 cases just mentioned, the differences in texture score between the two makes ranged from 0.25 to 2 points, and averaged 1.09 points.

Figure 5 shows that 90 per cent (48 out of 53) of the pasteurized-milk cheese texture scores lie between 26 and 27.50, a range of 1.50 points; while 94 per cent (50 out of 53) of the raw-milk cheese scores are quite evenly distributed between 25 and 27, a range of 2 points, a distinct advantage in favor of the new process, both as to quality and uniformity of texture.

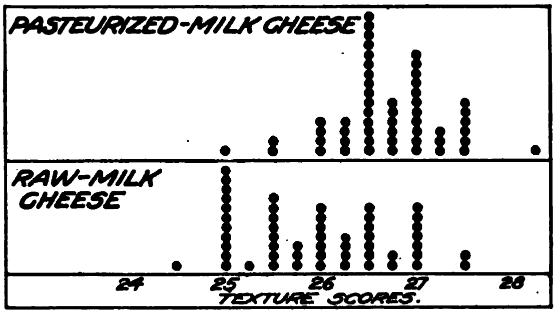

FIG. 5.—Distribution of texture scores of pasteurized and raw milk cheese.

CHEESE CURED IN THE SOUTH.

Lot 1B.—Four lots of cheese, lots 1B, 2B, 3B, and 4B, were shipped to New Orleans for storage, the first lot for two months and the other three for one month.

Lot 1B consisted of 25 pairs of cheese which were made on 25 days between February 23 and April 18, at Madison, and shipped to New Orleans April 29, arriving May 9. They were stored there until July 3, and then shipped back to Madison where they were scored separately on July 17, 1911, by Messrs. U. S. Baer and A. T. Bruhn. The temperatures at New Orleans given below are taken from the United States Weather Bureau monthly meteorological summaries. The average daily mean for May was 75.8°, with temperature on different days varying from 60 to 96. For June the average daily mean was 83.2°, with temperature on different days varying from 70 to 98. The quality of both the raw and pasteurized cheese after returning from New Orleans was very poor, as shown by the scores of the judges and by letters from dealers to whom they were afterwards sold at a reduced price. The average score of the 25 pasteurized-milk cheeses was 85.10 and of the 25 raw-milk cheeses 83.34, a difference of 1.76 points. In 17 cases out of 25 the pasteurized-milk cheese scored higher, in 3 cases equal to, and in 5 cases less than the raw-milk cheese. (See Table 40.) The highest average score given to any cheese in the lot was 90.5 and the lowest 78.50. The scores are shown in Table 40.

TABLE 40.—*Scores of 25 pairs of raw and pasteurized cheeses (lot 1B) cured for two months at New Orleans.*

Date made.	Cheese No.[1]	Total score (U. S. Baer).	Total score (A. T. Bruhn).	Average total score.
1911.				
Feb. 23	171	82	80	81
23	171C	87	87	87
24	172	83	79	81
24	172C	85	81	83
27	173	87	90	88.5
27	173C	85	86	85.5
28	174	90	85	87.5
28	174C	83	85	84
Mar. 1	175	86	87	86.5
1	175C	83	84	83.5
2	176	86	88	87
2	176C	83	84	83.5
3	177	88	84	86
3	177C	88	85	86.5
7	178	86	86	86
7	178C	86	85	85.5
8	179	91	90	90.5
8	179C	85	83	84
9	180	86	88	87
9	180C	85	85	85
10	181	90	88	89
10	181C	85	85	85
13	182	80	80	80
13	182C	80	80	80
14	183	79	79	79
14	183C	87	84	85.5
15	184	85	84	84.5
15	184C	85	82	83.5
16	185	85	89	87
16	185C	85	85	85
17	186	80	80	80
17	186C	80	80	80
20	187	79	80	79.5
20	187C	79	80	79.5
21	188	77	80	78.5
21	188C	80	80	80
22	189	86	83	84.5
22	189C	80	80	80
Apr. 5	198	92	89	90.5
5	198C	89	81	85
7	200	86	87	86.5
7	200C	82	85	83.5
11	202	85	88	86.5
11	202C	83	84	83.5
13	204	89	87	88
13	204C	84	84	84
17	206	89	86	87.5
17	206C	83	81	82
18	207	85	86	85.5
18	207C	83	84	83.5

[1] "C" in this column indicates raw-milk cheese.

It can be seen that storage for so long a period as two months in New Orleans, at such temperatures, can not be practiced with either raw or pasteurized cheese without great loss of quality; and that of the two lots, the pasteurized was somewhat the better when taken out of storage. On account of the unmarketable quality of both lots of cheese when scored it appears unnecessary to give the detailed score and criticisms as to flavor and texture.

Lots 2B, 3B, and 4B.—These lots were stored at New Orleans for one month each during parts of June, July, August, and September, 1911. The mean daily temperature during this period averaged 83.2° for June, 80.2° for July, 81.8° for August, and 82.6° for September. In lot 2B the 9 pasteurized-milk cheeses received an average total score of 90.44, and the raw-milk cheese of 85.56. The pasteurized was better in every case, and on the average 4.88 points better.

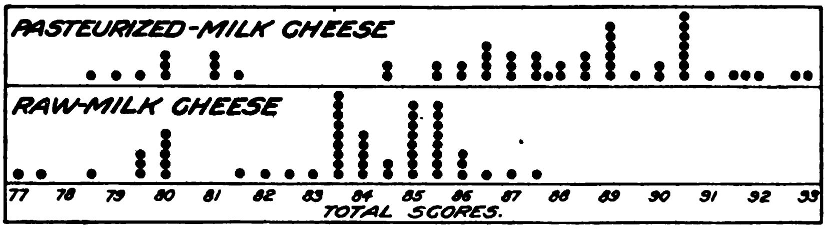

FIG. 6.—Distribution of total scores of pasteurized and raw milk cheese.

In lot 3B the 10 pasteurized-milk cheeses scored the highest in every case, the average being 7.7 points higher. The average score of the pasteurized was 90.30, and of the raw 82.60.

In lot 4B the 10 pasteurized-milk cheeses scored the highest in every case but one, and averaged 85.62, while the 10 raw-milk cheeses averaged 82.10, a difference of 3.52 points.

From the results shown in Tables 40 and 41 and in figure 6, it is clear that after storage in the South the pasteurized-milk cheese came out better in quality than the raw-milk cheese made from the same milk. It is not intended to suggest that cheese could be shipped to the Southern States with the express intention of storing it for one month before it is sold, but it is clear that during the few days or weeks necessarily elapsing after market cheese reaches its destination in the South and before it is eaten, the pasteurized-milk cheese is less likely to undergo serious deterioration than the raw-milk cheese.

TABLE 42.—*Scores of 29 pairs of raw and pasteurized cheeses (lots 2B, 3B, and 4B) cured for one month at New Orleans.*

LOT 2B, SCORED JULY 17, 1911, AT MADISON.

Date made.		Mean temperature at New Orleans.	Cheese No.[1]	Total score (U. S. Baer).	Total score (A. T. Bruhn).	Average total score.
1911.		°F.				
Apr.	24	46	211	90	88	89
	24	....	211C	85	86	85.5
	27	60	214	92	90	91
	27	....	214C	85	86	85.5
	28	55	215	93	90	91.5
	28	....	215C	85	84	84.5
May	2	66	216	90	88	89
	2	....	216C	85	86	85.5
	3	60	217	91	89	90.0
	3	....	217C	85	85	85
	8	71	220	90	87	88.5
	8	....	220C	85	58	85
	10	73	222	92	94	93
	10	....	222C	88	87	87.5
	15	76	225	89	91	90
	15	....	225C	87	85	86
	17	76	227	92	92	92
	17	....	227C	86	85	85.5

LOT 3B, SCORED AUG. 14, 1911, AT MADISON.

Date made.		Mean temperature at New Orleans.	Cheese No.[1]	Total score (U. S. Baer).	Total score (A. T. Bruhn).	Average total score.
May	22	78	230	89	88	88.5
	22	....	230C	83	84	83.5
	25	82	233	90	88	89
	25	....	233C	79	80	79.5
	29	84	234	91	90	90.5
	29	....	234C	83	82	82.5
June	1	86	237	91	90	90.5
	1	....	237C	80	81	80.5
	2	85	238	91	90	90.5
	2	....	238C	85	82	83.5
	7	83	240	92	89	90.5
	7	....	240C	80	79	79.5
	9	87	242	93	92.5	92.75
	9	....	242C	82	81	81.5
	13	88	243	92	90.5	91.25
	13	....	243C	86	85	85.5
	15	88	245	90	91	90.5
	15	....	245C	87	85	86
	16	86	246	89	89	89
	16	....	246C	86	82	84

LOT 4B, SCORED SEPT. 18, 1911, AT MADISON.

Date made.		Mean temperature at New Orleans.	Cheese No.[1]	Total score (U. S. Baer).	Total score (A. T. Bruhn).	Average total score.
June	19	76	248	88.5	87	87.75
	19	....	248C	83	85	84
	21	74	250	81	82	81.5
	21	....	250C	85	85	85
	26	80	253	87	88	87.5
	26	....	253C	87	85	86
	27	82	254	89	89	89
	27	....	254C	76	78	77
	28	80	255	80	80	80
	28	....	255C	78	77	77.5
July	3	82	258	85	86	85.5
	3	....	258C	82	85	83.5
	8	79	260	88	88	88
	8	....	260C	86	83	84.5
	10	82	261	62	80	81
	10	....	261C	79	78	78.5
	11	82	262	90	89	89.5
	11	....	262C	85	85	85
	12	79	263	87	86	86.5
	12	....	263C	80	80	80

[1] "C" indicates raw-milk cheese.

Lots 3C and 4C.—These two additional lots were stored for one month in the South and subsequently scored at Madison. In lot 3C the 10 pasteurized cheeses averaged 91 and the 10 raw-milk cheeses 84.85, as shown in Table 42. In every case the pasteurized cheese scored higher than the raw. In Lot 4C, the 10 pasteurized averaged 87.82 in total score, and the 10 raw-milk cheeses, 85.07, and in every case but one the pasteurized scored higher than the raw. All but two of these 40 cheeses scored below 92 and most of them were unsalable at full price, after storage as described. The temperature inside of the storage warehouse was not recorded.

TABLE 42.—*Scores of 20 pairs of raw and pasteurized milk cheese (lots 3C and 4C) stored one month in the South and scored at Madison.*

LOT 3C, STORED ONE MONTH AT COLUMBUS, GA., AND SCORED AT MADISON, AUG. 14, 1911.

Date made.	Cheese No.[1]	Total score (U. S. Baer).	Total score (A. T. Bruhn).	Average total score.
1911.				
Apr. 22	230	90	90	90
22	230C	87	86	86.5
25	233	90	89½	89.75
25	233C	85	84	84.5
29	234	94	94	94
29	234C	91	87	89
June 1	237	92	89	90.5
1	237C	85	83	84
2	238	90	91	90.5
2	238C	84	85	84.5
7	240	92	91	91.5
7	240C	78	79	78.5
9	242	91	93	92
9	242C	85	87	86
13	243	Lost.	Lost.	Lost.
13	243C	85	82	83.5
15	245	91	90	90.5
15	245C	89	84	86.5
16	246	90	90½	90.25
16	246C	88	83	85.5

LOT 4C, STORED ONE MONTH AT NEW ORLEANS, AND SCORED AT MADISON, SEPT. 18, 1911.

Date made.	Cheese No.[1]	Total score (U. S. Baer).	Total score (A. T. Bruhn).	Average total score.
1911.				
June 19	248	90	89½	89.75
19	248C	85	86	85.5
21	250	88	88	88
21	250C	85	85	85
26	253	86	87	86.5
26	253C	86	85½	85.75
27	254	90	89½	89.75
27	254C	80	83	81.5
28	255	89½	89½	89.5
28	255C	83	85	84
July 3	258	87	88	87.5
3	258C	86	86	86
8	260	89	90	89.5
8	260C	87	86	86.5
10	261	83	84	83.5
10	261C	87	86	86.5
11	262	85	85	85
11	262C	85	85	85
12	263	90	88½	89.25
12	263C	85	85	85

[1] "C" indicates raw-milk cheese.

CHEESE CURED IN WARM ROOM AT MADISON.

Lots 3D and 4D.—These lots of cheese were stored in a warm room at Madison where the temperature ranged from 70° to 80°, occasionally going up to 85°, during the months of July, August, and September, 1911. In lot 3D the pasteurized cheese scored higher than the raw-milk cheese in every case, averaging 90.55 to total score, while the raw-milk cheese averaged 83.75. In lot 4D the pasteurized cheese scored higher than the raw in every case but one, averaging 90.52, while the raw-milk cheese averaged 86.15, as shown in Table 43.

TABLE 43.—*Scores of 20 pairs of raw and pasteurized milk cheese (lots 3D and 4D) stored in warm room at Madison.*

LOT 3D, SCORED AUG. 14, 1911.

Date made.	Cheese No.[1]	Total score (U. S. Baer).	Total score (A. T. Bruhn).	Average total score.
1911.				
May 22	230	87	87	87
22	230C	85	86	85.50
25	233	90	89½	89.75
25	233C	81	80	80.50
29	234	93	94	93.50
29	234C	85	85	85
June 1	237	94	94	94
1	237C	80	80	80
2	238	90	91	90.5
2	238C	85	86	85.5
7	240	94	94	94
7	240C	79	79	79
9	242	92	92½	92.25
9	242C	85	85	85
13	243	90	89	89.5
13	243C	85	86	85.5
15	245	87	88	87.5
15	245C	85	86	85.50
16	246	88	87	87.5
16	246C	87	85	86
LOT 4D, SCORED SEPT. 18, 1911.				
June 19	248	91	91½	91.75
19	248C	85	85	85
21	250	86	86	86
21	250C	86	85	85.50
26	253	88	88	88
26	253C	85	86	85.5
27	254	91	92	91.5
27	254C	80	82	81
28	255	92	92½	92.25
28	255C	89½	89½	89.5
July 3	258	92	92	92
3	258C	87	86	86.5
8	260	91	92	91.5
8	260C	86	86½	86.25
10	261	85	85	85
10	261C	89	87	88
11	262	94	94	94
11	262C	86	88	87
12	263	93	93	93
12	263C	86	89	87.5

[1] "C" indicates raw-milk cheese.

CHEESE CURED IN COLD STORAGE.

Lot 4E.—Since much of the cheese made by the ordinary process is put into cold storage at about 34°, and most cheese dealers have cold-storage warehouses, a study was begun of the effect of cold storage on pasteurized-milk cheese. The milk supply was so short at the time that raw-milk cheese could be made on only a few days. Six or seven pasteurized-milk cheeses were made in one vat each day and placed in the curing room at Madison, and single cheeses were shipped to a cold-storage warehouse at Waterloo, Wis., at different ages. After about three months the cheese was all shipped back to Madison in one consignment and examined by the judges. One cheese from each day's make was kept at Madison during the entire period.

TABLE 44.—*Scores of pasteurized and raw milk cheese (lot 4E) put into cold storage at different ages and scored Oct. 30, 1911.*

Date made.		Cheese No.[1]	Age when stored.	Scored by U. S. Baer.			Scored by A. T. Bruhn.			Average score.		
				Flavor.	Texture.	Total.	Flavor.	Texture.	Total.	Flavor.	Texture.	Total.
1911.												
July	20	264.1	....	42.00	28.00	95.00	42.50	27.00	94.50	42.25	27.50	94.75
	20	264.2	1 day....	41.00	26.50	92.50	40.50	27.00	92.50	40.75	26.75	92.50
	20	264.3	1 week..	40.00	26.00	91.00	40.50	27.00	92.50	40.25	26.50	91.75
	20	264.4	2 weeks.	41.00	28.00	94.00	41.00	27.50	93.50	41.00	27.75	93.75
	20	264.5	4 weeks.	41.00	28.00	94.00	42.00	28.00	95.00	41.50	28.00	94.50
	20	264.6	6 weeks.	41.00	28.00	94.00	42.00	27.50	94.50	41.50	27.75	94.25
	20	265.1	....	41.00	27.00	93.00	41.00	26.50	92.50	41.00	26.75	92.75
	21	265.2	1 day....	40.00	27.00	92.00	41.00	26.50	92.50	40.50	26.75	92.25
	21	265.3	1 week..	42.00	28.00	95.00	42.00	28.00	95.00	42.00	28.00	95.00
	21	265.4	2 weeks.	40.00	27.00	92.00	40.00	27.00	92.00	40.00	27.00	92.00
	21	265.5	4 weeks.	40.00	27.00	92.00	40.00	27.00	92.00	40.00	27.00	92.00
	21	265.6	4 weeks.	40.00	27.00	92.00	41.00	27.00	93.00	40.50	27.00	92.50
	25	265.7	6 weeks.	41.00	28.00	94.00	42.00	27.00	94.00	41.50	27.50	94.00
	25	267.1	....	41.00	28.00	94.00	42.00	27.00	94.00	41.50	27.50	94.00
	25	267.2	1 day....	40.00	26.00	91.00	40.00	26.00	91.00	40.00	26.00	91.00
	25	267.3	1 week..	41.50	27.00	93.00	41.50	27.50	94.00	41.50	27.25	93.75
	25	267.4	2 weeks.	40.00	27.00	92.00	41.00	27.00	93.00	40.50	27.00	92.50
	25	267.5	4 weeks.	41.00	27.00	93.00	40.50	27.00	92.50	40.75	27.00	92.75
	25	267.6	6 weeks.	42.00	27.00	94.00	42.00	27.50	94.50	42.00	27.25	94.25
	25	267C1	....	36.00	26.00	87.00	36.00	26.50	87.50	36.00	26.25	87.25
	25	267C2	1 day....	38.00	27.00	90.00	39.00	27.00	91.00	38.50	27.00	90.50
	25	267C3	2 weeks.	38.00	27.00	90.00	38.50	27.00	90.50	38.25	27.00	90.25
	27	269.1	....	40.00	27.00	92.00	41.00	26.50	92.50	40.50	26.75	92.25
	27	269.2	1 day....	40.00	27.00	92.00	40.50	26.50	92.00	40.25	26.75	92.00
	27	269.3	1 week..	40.00	27.00	92.00	40.50	26.50	92.00	40.25	26.75	92.00
	27	269.4	2 weeks.	41.00	27.00	93.00	40.00	26.50	91.50	40.50	26.75	92.25
	27	269.5	4 weeks.	41.00	27.00	93.00	42.00	27.00	94.00	41.50	27.00	93.50
	27	269.6	6 weeks.	42.50	28.00	95.50	42.50	27.50	95.00	42.50	27.75	95.25
	27	269C1	2 weeks.	34.00	23.00	82.00	32.00	25.00	82.00	33.00	24.00	82.00
Aug.	1	272.1	....	35.00	23.00	83.00	36.00	25.00	86.00	35.50	24.00	84.50
	1	272.2	1 day....	36.00	25.00	86.00	36.00	25.00	86.00	36.00	25.00	86.00
	1	272.3	1 week..	37.00	25.00	87.00	39.00	24.00	88.00	38.00	24.50	87.50
	1	272.4	2 weeks.	38.00	25.00	88.00	38.00	25.00	88.00	38.00	25.00	88.00
	1	272.5	4 weeks.	35.00	25.00	85.00	36.00	24.00	85.00	35.50	24.50	85.00
	1	272.6	6 weeks.	37.00	24.50	86.50	38.00	25.00	88.00	37.50	24.75	87.25
	8	276.1	....	37.00	25.00	87.00	39.00	26.00	90.00	38.00	25.50	88.50
	8	276.2	1 day....	40.00	26.00	91.00	40.00	26.00	91.00	40.00	26.00	91.00
	8	276.3	1 week..	40.00	25.00	90.00	39.50	25.50	90.00	39.75	25.25	90.00
	8	276.4	2 weeks.	40.00	24.00	89.00	39.00	25.00	89.60	39.50	24.50	89.00
	8	276.5	4 weeks.	40.00	27.00	92.00	39.50	26.50	91.00	39.75	26.75	91.50
	22	283.1	....	41.00	27.00	93.00	41.50	26.50	93.00	41.25	26.75	93.00
	22	283.2	1 day....	40.00	26.00	91.00	40.50	26.00	91.50	40.25	26.00	91.25
	22	283.3	1 week..	42.00	27.00	94.00	41.00	27.00	93.00	41.50	27.00	93.50
	22	283.4	2 weeks.	40.50	27.00	92.50	41.00	26.50	92.50	40.75	26.75	92.00
	22	283.5	4 weeks.	42.00	27.00	94.00	41.50	27.00	93.50	41.75	27.00	93.50
	22	283.6	....	42.00	27.00	94.00	42.00	26.50	93.50	42.00	26.75	93.75

[1] "C" in this column indicates raw-milk cheese.

In every case the pasteurized-milk cheese put into cold storage at the age of one day was criticized by the judges as being flat, low, and not developed in flavor, and the texture was described as curdy, new, not broken down, not cured, etc. They received an average score of 90.84, as shown in Table 44.

The cheeses put into cold storage at the age of one week received an average score of 91.93. They were found to be well cured, and they had less mold on the surface (practically none), both when put into storage and when taken out, than any of the later lots. The cheeses put into storage at two weeks, four weeks, and six weeks of age were given average scores of 91.36, 91.82, and 91.46, respectively, while those kept at Madison for the entire period scored 91.39.

So far as this short series indicates, there is no objection to putting pasteurized-milk cheese into storage at 34°, at the age of one week, immediately after paraffining. It was planned, however, to make a more extensive trial of the use of cold storage for pasteurized-milk cheese during the season of 1912.

EXCEPTIONAL DIFFERENCES BETWEEN THE RAW AND PASTEURIZED MILK CHEESE.

It is of interest to collect in one place all of the cases recorded in the tables where the pasteurized-milk cheese was scored lower than the raw, in order if possible to locate the cause for such difference.

TABLE 45.—*Summary of cases in which raw-milk cheese scored higher than pasteurized.*

Lots 1A, 2A, 3A, 4A.		Lots 1B, 2B, 3B, 4B.		Lots 3C, 4C.		Lots 3D, 4D.	
Cheese No.[1]	Total Score.	Cheese No.[1]	Total Score.	Cheese No.[1]	Total Score.	Cheese No.[1]	Total Score.
		171	81.00				
		[2] 171C	87.00				
172	91.75	172	81.00				
172C	89.50	[2] 172C	83.00				
177	91.75	177	86.00				
177C	89.00	[2] 177C	86.50				
183	91.25	183	79.00				
[2] 183C	91.75	[2] 183C	85.50				
184	92.00	184	84.50				
[2] 184C	92.75	184C	83.50				
188	94.50	188	78.50				
188C	90.50	[2] 188C	80.00				
250	91.75	250	81.50	250	88.00	250	86.00
250C	87.50	[2] 250C	85.00	250C	85.00	250C	85.50
261	90.25	261	81.00	261	83.50	261	85.00
261C	90.00	261C	78.50	[2] 261C	86.50	[2] 261C	88.00

[1] "C" indicates raw-milk cheese.

[2] These are the cases in which the raw-milk cheese scored higher than the pasteurized. The other scores of duplicate cheese in the other lots are given for comparison.

The fact that pasteurized and raw cheese from the same milk may occasionally score exactly alike or nearly alike would appear to indicate that where the milk supply is excellent the quality of cheese produced is not improved by the new process. With so small a difference in score as half a point, occurring in No. 184 in lot A and No.

177 in lot B, it is doubtful whether there was any difference between the two cheeses which could be ascribed with certainty to the effect of the pasteurization process.

The most adverse criticism on the process that can be based upon the 10 cases tabulated above is the following: It is entirely possible that some harmful bacteria or their enzyms which are occasionally present in dirty milk may not be destroyed by the pasteurization process and that such infections damage the quality of pasteurized-milk cheese as well as raw-milk cheese. In this year's work it has been noticed that on a few occasions when the raw milk was very ripe the quality of cheese produced, even after pasteurization, was not so good as from milk of fairly good quality. For example: The poorest pasteurized-milk cheese in Table 45 is No. 261, and the milk used for making this was of 0.28 per cent acidity before pasteurization. In Table 44, showing the scores of cheese shipped to cold storage, Nos. 272 and 276 are the poorest in quality and these were made from milk which titrated 0.275 and 0.31 per cent acidity, respectively, before pasteurization. Of course such milk should not be accepted at any cheese factory.

No claim is made that the pasteurization process is a cure for all the troubles of the cheese factory, or that it reduces the responsibility resting on factory patrons to improve the sanitary quality of their milk. It would, in fact, be most unfortunate if any process could be used for making cheese, or any other article of food, which would relieve the milk producer or the factory man of the necessity for cleanliness.

SUMMARY OF DISCUSSION OF SCORES.

The scores of lots 1B, 2B, 3B, and 4B, 3C and 4C, and 3D and 4D all show that cheese, either raw or pasteurized, stored for one or two months at about 80° are often seriously injured, so as to be unsalable at the ruling market price. The pasteurized cheese came out of such storage better in quality than the raw-milk cheese in about 90 per cent of all the cases observed. It is clear that pasteurized-milk cheese is better suited to stand exposure to high temperature than raw-milk cheese. This fact may find useful application in two ways: While it is never advisable to store market cheese for any great length of time in the South, yet several days or weeks may often elapse before cheese shipped South is finally sold to the consumer, and it appears that pasteurized-milk cheese should stand this exposure with less damage in quality than raw-milk cheese. It is likely, too, that pasteurized-milk cheese can be cured at ordinary curing-room temperatures below 70° in Wisconsin without the use of ice or mechanical refrigeration, thus avoiding part of the expense for cold storage. The quality of the 53 raw-milk cheeses in lots 1A, 2A, 3A, and 4A, cured at 60° to 73° at Madison, is represented by the average total score of 89.09, and would no doubt have been greatly improved if the cheese had been cured in cold storage. In 51 cases out of 53 the pasteurized-milk cheese in these lots scored higher than the raw, on the average 3.8 points higher, the average total score of the pasteurized being 92.75 points, which indicates that cold storage for the pasteurized cheese was not necessary.

In a short series of cheese placed in cold storage at 34° F. at different ages, it was found that those stored at the age of one day were curdy and uncured at the age of three months, while those placed in storage at the age of one week were free from this fault and scored as high, even a little higher, and showed less mold on the surface than those put in storage when older than one week. From this it appears that pasteurized-milk cheese can be safely put in cold storage at the age of one week immediately after paraffining. It was planned to try cold storage with both raw and pasteurized-milk cheese during 1912.

THE DEMAND FOR PASTEURIZED-MILK CHEESE.

One of the objects of the work during 1909, 1910, and 1911 was to sell the cheese to consumers as widely as possible, and learn whether it would meet with favor and continued demand. It was felt necessary thus to establish its suitability for the market before recommending cheese makers to take up the new process.

The amount of pasteurized-milk cheese sold each year was limited by the output of the factory, it being impossible to secure a larger supply of milk. Much more cheese could have been sold to the same purchasers, and doubtless to others, if we had had the cheese to sell. In nearly all cases the cheese was sold at the current price ruling on the Plymouth cheese board, f. o. b. Madison without discount. During 1910, 4,815½ pounds of pasteurized-milk cheese valued at $711.16 were sold to 19 representative grocery stores, hotels, restaurants, and delicatessen stores in Madison, Wis. The total number of such sales was 137 during the season. Nearly every purchaser reordered it several times, and three of the leading retailers reordered it 15, 20, and 49 times, respectively, during the season. The average price paid for all of this cheese was 14¾ cents per pound. During 1909, 1910, and 1911, 41 shipments of pasteurized-milk cheese weighing 10,126 pounds in all and valued at $1,382.93 were sent to 27 leading cheese dealers, including a few retail stores, at New York, Boston, Philadelphia, Chicago, St. Louis, Minneapolis, and San Francisco, and at various Wisconsin points outside of Madison, including Plymouth, Sheboygan, Fond du Lac, Marshfield, Richland Center, Waterloo, and Milwaukee. Samples of the cheese were also shipped to experiment station workers in the leading dairy States for an examination.

OPINIONS OF PURCHASERS.

No written opinions were asked from dealers in Madison handling the pasteurized-milk cheese, neither were they urged to purchase a second time. The university delivery wagon making two trips daily among retail stores took such orders as were given. The fact that a dealer bought this make of cheese only once may be due to a variety of causes, such, for example, as business relations with other wholesale cheese dealers in the city. The fact that several of the leading grocers sold this cheese continuously for several months and repurchased it every week or oftener, and always without reporting any complaint from consumers, is taken to indicate that it was satisfactory to the retail trade of this city.

An effort was made to obtain a written opinion from every firm outside of Madison to whom the cheese were sold. It was usually impossible to send many shipments to a single purchaser, because it was desired to distribute the available supply of cheese as widely as possible.

The letters received from dealers outside of Madison show that all except a very few found the cheese to be entirely satisfactory, and salable at the full market price. Here again the occasional disapproval of a cheese may be due to an oversupply in the buyer's warehouse, or other causes than the quality of the cheese iteslf. It is interesting to note that pasteurized-milk cheese shipped to two firms who apparently disliked it was the same day's make as others shipped on the same date to three other firms who praised their quality and pronounced them satisfactory. In every case dealers were informed that the cheese "was made by special process, which we are trying at Madison, by which it is hoped that cheese of cleaner flavor and greater uniformity can be obtained." In no case were dealers informed as to the nature of the process or that the milk was pasteurized. The purpose was to excite the dealers' interest and secure careful examination of the cheese, unqualified by any prejudice for or against pasteurization.

The very general expression of approval of the product in the letters from dealers and experiment stations appears to warrant further trial of the method on a larger scale than heretofore.

THE EXTRA COST OF MAKING PASTEURIZED-MILK CHEESE.

While it has been shown that an increased yield of cheese is obtained there are also additional costs, which must be charged against the cheese made by this method. Such costs will include the interest on investment, and depreciation, of a pasteurizer, cooler, and receiving vat, a charge for the hydrochloric acid used and for the expense of steam heat and power for pumping water for cooling the pasteurized milk, and for running the pasteurizer.

Preliminary estimates, based upon available data, seem to indicate that the extra cost of making pasteurized-milk cheese is less than the additional value of the cheese, leaving a net profit from the use of the process, as compared with the regular factory process. Since the steam and water supplies used in the work at Madison were drawn from the general service pipes of the Wisconsin Agricultural Experiment Station it was impossible to determine these items of cost with exactness.

In order to ascertain precisely what the charges for steam heat, power, etc., are at an average cheese factory in Wisconsin, a complete outfit for making pasteurized-milk cheese will be set up at a country cheese factory, easily accessible from Madison, and operated by an experienced and successful cheese maker. Cheese will be made there by both the regular factory method and by the new method in order to ascertain more fully the cost of making, the increased yield, and the market value of pasteurized-milk cheese.

FURTHER TRIALS OF THE NEW PROCESS IN CHEESE FACTORIES.

The results described in this bulletin appear to indicate that the new method of cheese making is an improvement over the regular process now commonly used. Working with the milk supply available at Madison, the new method is unquestionably an improvement over the old. It is a fact well known to cheese makers, however, that the milk supplies found at different factories do not always behave alike in the cheese vat, so that the old process must frequently be modified to suit the conditions encountered in different localities. It remains, therefore, to test the new method at several factories in different cheese-making districts before it can be recommended for use generally. Cheese makers are advised to await the publication of results of further trials before undertaking to use the new method on a commercial scale.

It is hoped that the new method will receive careful attention and criticism by such cheese experts at experiment stations in different parts of the country as may be able to give it a trial. The authors will be glad to correspond with any one interested and to aid in such trials so far as circumstances permit.

SUMMARY.

PRELIMINARY AND COMPARATIVE WORK WITH THE OLD AND NEW METHODS.

The continued improvement of the cheese-making industry calls for more economical factory management. Large, well-equipped factories should replace many of the small, poorly supported factories of the present time.

To enable cheese factories to handle milk from larger areas of territory, and for other reasons also, a new method of cheese making is needed by means of which milk of variable quality from many farms can (1) be brought into practically uniform condition for cheese making at the factory, and (2) can be made up into cheese in a uniform, routine manner daily without variations of time or method of handling; also (3) cheese of greater uniformity should be produced, and (4) the losses in yield and quality of cheese due to defective milk, now common in factories, should be avoided.

During the years 1905 and 1906 experimental cheese was made without starter, adding in its place to the raw milk some commercial acid, as hydrochloric acid or other kinds. The method of adding the acid to milk was perfected, and a two weeks' trial of the process was finally made in a commercial factory at Muscoda, Wis. It was shown clearly that the addition of hydrochloric acid to milk in a cheese factory is entirely practicable and that the quality of the cheese is not in any way injured by such addition, but it was also found that the quality of cheese obtained from overripe or tainted milk was no better than by the use of the ordinary factory methods. Therefore, there was no reason for recommending the use of hydrochloric acid to cheese makers at that time.

Most of the defects observed in cheese-factory milk are of bacterial origin, and in other branches of the dairy industry pasteurization is successfully employed to overcome these faults. The desirability of pasteurizing milk for cheese making, if possible, has often been pointed out.

In 1907 a few lots of milk were pasteurized in a discontinuous pasteurizer and acidulated with hydrochloric acid, and the cheese obtained was such as to demonstrate the importance of further study.

In 1908 equally good results were obtained by use of the continuous pasteurizer. A temperature of 160° to 165° was decided upon as being sufficiently high to effectually check bacterial action in milk for cheese-making purposes. Bacterial counts showed that over 99 per cent of the total bacterial content of the milk was destroyed at this temperature. The use of higher temperatures was shown to be objectionable on account of the effect upon the quality of the cheese.

In 1909 cheese was made almost daily both by the regular factory process and by the new process from pasteurized milk. The regular milk supply was thoroughly mixed each day and divided into two lots for the two different processes. The cheese made from pasteurized milk was found after curing to be cleaner in flavor and superior in texture to the raw-milk cheese. The difference was more marked the poorer the quality of the milk supply. Many of the details of the process were studied and improved.

In 1910 the making of cheese by the two methods for comparison was continued, and the entire output of pasteurized-milk cheese was sold to retail grocers, mostly in the city of Madison, in order to determine how this cheese would suit the trade. The cheese met with ready and continued sale. It was noticed also that the yield of cheese was, regularly, somewhat greater by the new process than by the old.

In 1911 better facilities were provided for weighing large quantities of milk and cheese quickly and accurately, and the yields of cheese obtained from raw and pasteurized milk were carefully determined. The accuracy of the experimental methods was such that in making duplicate vats of cheese from pasteurized milk the yields differed by only 0.58 per cent on the average. A greater yield of cheese was always obtained from the pasteurized milk than from raw milk, and during the year 1911 the average gain in yield of green cheese was 5.37 per cent. However, the green pasteurized-milk cheese shrank a little more than the raw-milk cheese, so that when paraffined the average gain in yield from pasteurized milk was 4.76 per cent. After curing cheese at 60° to 70° F. for about 100 days, the gain in yield of pasteurized-milk cheese over the raw was 4.22 per cent.

SOME ADVANTAGES FROM THE USE OF PASTEURIZED MILK AND HYDROCHLORIC ACID.

The average loss of fat in whey from pasteurized-acidulated milk is about 0.17 per cent measured at the time the whey is drawn from the vat. This is less than half the loss in average factories using raw milk. The total loss of fat in whey and drippings from vat and press, using pasteurized milk with acid, averaged 1.58 per cent of the weight of the cheese, or less than one-half of the usual loss in handling raw milk.

In addition to this saving of fat, it is found that a somewhat larger proportion of moisture can be incorporated in pasteurized-milk cheese than in ordinary cheese, without damage to the quality. The gain in the yield of pasteurized-milk cheese is due partly to fat and partly to moisture.

Scores and criticisms made by competent cheese judges show that the pasteurized-milk cheese varies less in quality and averages better by 3.7 points of total score than the raw-milk cheese made from portions of the same milk supply. In 96 per cent of all cases the pasteurized-milk cheese scored higher than the raw-milk cheese.

Duplicate sets of cheese were cured at New Orleans for one month at 70° to 83° (monthly average figures during the summer), and here the raw milk lost more in weight than the pasteurized, so that the average gain in yield of pasteurized over raw rose to 6.21 per cent.

From other cheese cured at Madison on tin pans in a warm room, it was learned that the raw-milk cheese lost considerable amounts of fat at 75° to 85° while the pasteurized-milk cheese lost none.

Storage for a month at an average temperature of 75° to 80° at New Orleans is not recommended for any cheese, yet it was found that pasteurized-milk cheese averaged 3 to 8 points better in total score after such storage than raw-milk cheese.

Since pasteurized-milk cheese can be cured without injury at 70°, it is likely that in most cases the expense of cold storage for this cheese can be avoided.

Pasteurized-milk cheese can be put into cold storage at 34° at the age of one week and possibly earlier without injury. The earlier the cheese can be put in storage, if this is done at all, the greater will be the gain in yield by the new process. It is planned to study the cold storage of this cheese further.

During 1910–1911 about $2,100 worth of pasteurized-milk cheese was sold to about 50 dealers, both wholesale and retail, in various large cities from New York to San Francisco. The cheese sold readily for the ruling market prices and often above. Very few dealers offered any objections to them and several wished to buy them regularly. A good many were sold throughout the South by dealers. In general, the cheese passed through the market without exciting special comment, selling for full price and giving satisfaction. They were not labeled or marked except with a number for purposes of identification. There appears to be no reason why pasteurized-milk cheese can not be sold regularly in any market with entire satisfaction, excepting possibly to the limited trade that demands very high-flavored cheese.

OUTLINE OF THE NEW METHOD.

In the method here described a principle is applied to the cheese-making process which has already been found useful in many other lines of manufacture, namely:

The raw material, milk, is first treated by a preparatory process to bring it into uniform condition before it enters the manufacturing process proper. Material of uniform quality thus prepared is made up into the finished product by a uniform routine process without daily variations of the time schedule or other details, and the product is more uniform in quality, has better keeping qualities, etc., than the product obtained by the older process.

The difficulties met with hitherto in making American Cheddar cheese from pasteurized milk are:

First. That heated milk coagulates poorly with rennet; and

Second. The curd when obtained does not expel moisture precisely as a raw-milk curd does, and this effect is more marked the higher the temperature of pasteurization. The quality and behavior of pasteurized-milk curd suggest that it lacks the acid which is normally produced in raw-milk curds by the action of bacteria on milk sugar.

The first of these difficulties, but not the second, can be overcome by adding calcium-chlorid solution to pasteurized milk. This method has been tried experimentally, but is not recommended for use in American cheese factories. Both difficulties, however are overcome by adding an acid, preferably hydrochloric, to the pasteurized milk. Hydrochloric acid is normally present in the human stomach during the process of digestion in larger proportions than that added to milk in this process of cheese making. Further, 95 per cent of the added acid passes out of the cheese with the whey during the process of manufacture. On this account no objection can be made on sanitary grounds to the use of this acid in the manner and for the purposes described.

Among different lots of cheese, part of which was made with hydrochloric acid and part with calcium chlorid added to portions of the same milk after pasteurization, those made with acid were found to be more uniform in moisture content and superior both in flavor and texture to those made with calcium chlorid. The losses of fat in the whey are reduced by the use of the acid. Pasteurization and acidulation of milk for cheese making appear to be complementary processes. Used together they furnish a means for bringing milk daily into uniform condition both as to acidity and bacterial content for cheese-making purposes.

The acidulation of milk with hydrochloric acid after pasteurization is accomplished without difficulty or danger of curdling by running a small stream of the acid, of normal concentration, into the cooled milk as it flows from the continuous pasteurizer into the cheese vat. One pound of normal-strength acid is sufficient to raise 100 pounds of milk from 0.16 per cent to 0.25 per cent acidity (calculated as per cent of lactic acid). The amount of acid needed each day to bring the milk up to 0.25 per cent acidity is read from a table or calculated from the weight of the milk and its acidity, determined by the use of Manns's acid test (titration with tenth-normal sodium hydrate and phenolphthalein). The preparation of standard-strength acid in carboy lots for this work and the acidulation of milk present no great difficulty to anyone who is able to handle Manns's acid test correctly.

After the milk is pasteurized and acidulated three-fourths per cent of first-class starter is added and the vat is heated to 85°. It is set with rennet, using 2 ounces of rennet per thousand pounds of milk, so that the milk begins to curdle in 7 minutes and is cut with three-eighth inch knives in 25 minutes. All portions of the work after adding rennet are carried out in an unvarying routine manner, according to a fixed-time schedule every day. As soon as the rennet has been added the cheese maker is able to calculate the exact time of day when each of the succeeding operations should be performed, and the work of making the cheese is thus simplified and systematized. It is possible that the routine process here described may be varied somewhat with advantage at different factories. For example, some experienced cheese makers may prefer to mat the curds on the bottom of the vat instead of on racks or may find the use of the "curd gauge" unnecessary, and local conditions may be found in different factories making other adjustments of details desirable. However, the experience already had with the process indicates that the routine of daily operations found suitable at any factory can be practiced there throughout the season without variation.

It is the intention to give the new process a thorough trial in different cheese factories in various localities to test its applicability to different milk supplies before recommending it for general use by cheese makers. These trials will show whether new difficulties may arise which were not encountered heretofore. Cheese makers are therefore advised to await the publication of results of further trials of the method by the writers before undertaking to use the new process at their factories.

The extra cost of making pasteurized-milk cheese is being studied with a view to finding out accurately what the net profit is in making this cheese compared with the regular process.

The new process should interest the farmer because of the increased yield and the avoidance of the usual losses in yield and quality of cheese due to defective milk. It should interest the cheese maker because the process of making is systematized to such a degree that it is conducted upon a fixed-time schedule for all operations. It should interest the dealer because the cheese is more uniform in quality and there is less need for cold storage in curing. Finally, the cheese should interest the consumer, because it is more uniform in flavor than most of the cheese to be found on retail counters and because it is made from pasteurized milk and is therefore a more sanitary product than ordinary American cheese made from raw milk.

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U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ANIMAL INDUSTRY.—BULLETIN 166.
A. D. MELVIN, CHIEF OF BUREAU.

CHEMICAL CHANGES PRODUCED IN COWS' MILK BY PASTEURIZATION.

BY

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Animal Industry,
Washington, D. C., January 30, 1913.

Sir: I have the honor to transmit for publication as a bulletin of this bureau the accompanying manuscript, entitled "Chemical Changes Produced in Cows' Milk by Pasteurization," by Dr. Philip Rupp, chemist in the Dairy Division of this bureau. The paper describes a series of experiments made with the object of determining the effect of pasteurization at various temperatures on the chemical composition of cows' milk. The work was undertaken because of certain objections which are made against pasteurization, it having been asserted that the process injures the milk from a digestive and nutritive standpoint, particularly as a food for infants. It is satisfactory to note from the results of the work that, so far as the ordinary temperatures used in commercial pasteurization are concerned, these objections are not well founded.

The method of filtering the milk necessary for the carrying on of the tests consists of a new application by Dr. Rupp of the clay-cell filtration used by other scientists. This method is fully described and illustrated by a diagram.

Respectfully,

A. D. Melvin,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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CHEMICAL CHANGES PRODUCED IN COWS' MILK BY PASTEURIZATION.

INTRODUCTION.

One of the objections frequently raised against pasteurized milk is that the heating produces changes in the chemical composition which make it unsuitable for infant nourishment. It is claimed that a portion of the soluble phosphate of lime becomes insoluble and that this change produces defective nutrition, while the changes in the lactalbumin and in the casein render the pasteurized milk more indigestible than raw milk, and therefore inferior as a food. These objections were brought forward at a time when high temperatures were employed in the sterilization of infants' milk, and they are made use of at the present day by the opponents of pasteurization, even though the temperatures used in pasteurizing are considerably lower.

The objects of the work herein described were to study the chemical changes produced by the heating of milk at the different temperatures used in commercial pasteurization and to determine whether a temperature that destroys all pathogenic germs can be used in pasteurization without having any appreciable effect on the chemical composition of the milk. Three points are considered: First, the changes in the phosphates are discussed in order to show to what extent the soluble phosphate of lime becomes insoluble. Second, the proteins are examined to determine to what extent the albumin is precipitated and the casein changed in its characteristic property of coagulating with rennin. Finally, the acidity of the milk is considered.

METHOD OF PASTEURIZATION EMPLOYED.

The milk was pasteurized in a constant-temperature bath. The water having reached the required temperature, the cool milk, in an Erlenmeyer flask closed with a valve to prevent evaporation, was placed in the water and occasionally moved about until it had acquired the temperature of the water. This usually required from 15 to 20 minutes, according to the height of the temperature. It was then allowed to remain for 30 minutes, after which it was rapidly cooled to about 12° C. (53° F.). The milk used was of very good quality and had a very low bacterial count. The variation in temperature during pasteurization was less than 0.5° C. (0.9° F.).

CHEMICAL CHANGES IN THE PHOSPHATES.

The vast majority of the experiments which show a diminution in the quantity of soluble calcium salts in heated milk as compared with raw milk refer to milk which has been heated to the boiling point. But few definite results can be found showing a diminution of the soluble calcium phosphate in pasteurized milk.

Diffloth[1] found a decrease in the soluble phosphates, amounting to a loss of 25.9 per cent, on heating milk to 60° C. (140° F.) for 30 minutes, while Babcock[2] believes that a change in the solubility of the lime salts is brought about when the milk is pasteurized, and bases his conclusion on the less ready coagulability of the milk by rennet.

In order to determine the effect of pasteurization on the solubility of the phosphates in the milk, the serum of both raw and pasteurized milk was examined.

METHOD OF FILTRATION.

A new application of the clay-cell filtration as used by Soxhlet[3] was employed. The clay cell of a galvanic element is thoroughly cleansed by boiling in dilute caustic soda and then washed by filtering hot water through the cell by suction. The cell is next boiled in dilute hydrochloric acid and again washed by suction with hot distilled water until the filtrate no longer gives a reaction for chlorin.

The method of filtration is easily understood by a description of the accompanying diagram (figure 1).

An inverted bell jar (*a*) (9 inches high and 4 inches in diameter) is covered with a perforated glass plate (*b*) holding a tube containing a plug of cotton to admit air. Inside the jar is a porous clay cell (*c*) of a galvanic element (5¼ inches high, 2⅜ inches in diameter, and the cell wall one-eighth of an inch thick) the opening of which is covered with a piece of rubber dam (*d*) of medium thickness and supported on a heavy glass plate (*e*). Both the rubber dam and the glass plate are perforated for the passage of a rubber stopper containing a glass tube with a Geissler stopcock (*f*). The upper end of the tube is flush with the glass plate *e*, while the lower end passes into a filtering flask (*g*) of 750 c. c. capacity. A glass tube with a two-way stopcock (*h*) is attached to the outlet of the flask, and this in turn is connected with the suction apparatus by means of a heavy rubber tube. In order to obtain airtight joints a little stopcock grease is placed on the glass plate, and the edge of the clay cell is also coated with a thin layer. The cover (*b*) of the bell jar is held down in the same manner.

---

[1] Diffloth, Paul. Du rôle de quelques agents physiques et chimiques dans l'insolubilisation des phosphates du lait. Bulletin des Sciences Pharmacologiques, vol. 10, p. 273-279. Paris, 1904. Abstract: Zeitschrift für Untersuchung der Nahrungs- und Genussmittel, vol. 11, no. 7, p. 455–456. Berlin, Apr. 15, 1906.

[2] Babcock, S. M. The centrifugal separation of casein and insoluble phosphates from milk. Wisconsin Agricultural Experiment Station, Twelfth Annual Report (1895), p. 93–99. Madison, 1896.

[3] Soxhlet, Franz. Beiträge zur physiologischen Chemie der Milch. Journal für Praktische Chemie, new series, vol. 6, no. 1/2, p. 1–52. Leipsic, Aug. 24, 1873.

To begin filtration remove the cover, evacuate the apparatus, and while the suction is still on fill the bell-jar with milk. Then cut off the suction at *h*, replace the cover, and remove the suction tube. The apparatus is now ready to be placed in the refrigerator.

The advantage of this method over those previously employed is that the filtration can be continued indefinitely and the serum removed at any time without interfering with the filtration. Furthermore, no concentration of the serum can take place, as evaporation is excluded. The serum can be removed at any time by closing the stopcock *f*, admitting air by opening *h*, and removing the filtering flask. Then replace the flask, evacuate, close the stopcock *h*, and open *f*, and the apparatus is ready for further filtration.

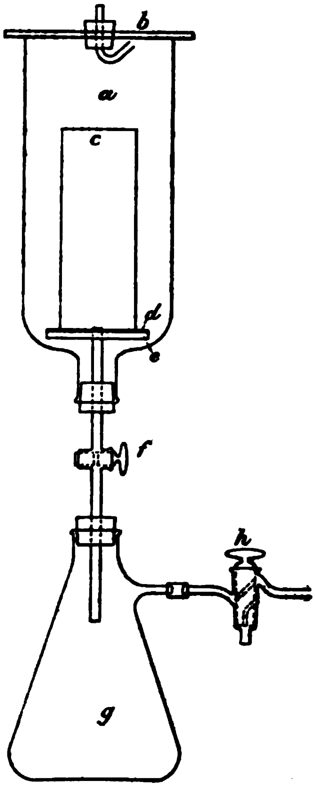

FIG. 1.—Apparatus for filtering milk.

METHODS OF ANALYSIS.

Weigh about 40 grams of milk (equivalent to about 0.1 gram of phosphoric acid), evaporate to dryness, and ignite at a low red heat until the ash is free from carbon. Dissolve the ash in hot water containing a little hydrochloric acid and dilute to about 100 c. c.

Basic acetate precipitation.—Almost neutralize the solution of the ash with ammonia, add 2 c. c. of dilute acetic acid and a slight excess of ferric chlorid solution of known strength (7.5 c. c. of a 10 per cent solution). Now add 13 to 14 c. c. of a 10 per cent ammonium acetate solution, dilute to 350 to 400 c. c. and boil for about one-half to one minute, stirring occasionally to prevent bumping. If the quantity of ferric chlorid added was sufficient the precipitate will be brownish-red, and the precipitation will be complete as the boiling point is reached if the acetate was added in sufficient quantity. Filter boiling hot through two 12.5 cm. filters and wash immediately with a hot dilute ammonium acetate solution (one-half to one per cent), using a fine jet which is played around the edge of the precipitate, thus cutting it free from the paper in order to produce rapid filtration. Do not allow to drain dry. Wash the precipitate in this manner three to four times until free from chlorids, return to the original beaker with hot water, and dissolve by the addition of nitric acid. When the basic acetate precipitation is carried out as described above the filtration is always rapid and the precipitate never runs through the filter. In washing the precipitate with hot water, some flakes generally appear on concentrating the filtrate and washings. This, however, is not the case if a hot dilute solution of ammonium acetate is used.

The phosphoric acid in the basic acetate precipitate was determined by the molybdate method and weighed as magnesium pyrophosphate. The filtrate and washings from the basic acetate precipitation were concentrated and the calcium precipitated with ammonium oxalate. The oxalate was redissolved, reprecipitated, and weighed as calcium oxid. The filtrate and washings from calcium precipitation were evaporated, ammonium salts removed, and the magnesium determined as pyrophosphate.

For serum analysis evaporate about 70 grams and ignite at a dull red heat until the ash is free from carbon. In the basic acetate precipitation use 6 c. c. of ferric chlorid solution and 9 to 10 c. c. of ammonium acetate solution.

The casein phosphorus was determined by Neumann's method,[1] using, however, only 10 c. c. of concentrated sulphuric acid. The total phosphorus in the milk was also determined by Neumann's method.

The specific gravity was taken by means of a picnometer.

CHANGES IN THE COMPOSITION OF THE SERUM DURING FILTRATION.

De Vries and Boekhout,[2] using a Chamberland filter and pressure, found that the quantity of calcium in the serum did not vary in different fractions during the filtration, the first 20 c. c. of serum containing the same quantity of calcium as the second and third. In order to determine whether the serum remains of constant composition during filtration and for what length of time milk can be filtered at a temperature of 5° to 8° C. (41° to 46. 4° F.) without changing its composition, skim milk was filtered and the serum analyzed during a period of two weeks. Skim milk was used for this experiment because it filters more rapidly than whole milk. The results are shown in Table 1.

---

[1] Neumann, Albert. Einfache Veraschungsmethode (Säuregemisch-Veraschung). Zeitschrift für Physiologische Chemie, vol. 37, no. 2, p. 115-142. Strasburg, Dec. 20, 1902.

[2] Ott de Vries, J. J., and Boekhout, F. W. J. Beitrag zur Kenntnis der Labgerinnung. Die Landwirtschaftlichen Versuchs-Stationen, vol. 55, no. 3, p. 221-239. Berlin, Feb. 12, 1901.

TABLE 1.—*Quantity of soluble phosphorus in the serum on different days during the filtration of raw skim milk, separated at 30° C. (86° F.).*

	Quantity.	Specific gravity.	Acidity.[1]	P_2O_5.	CaO.	MgO.
	Grams.			*Per cent.*	*Per cent.*	*Per cent.*
Casein				0.0638		
Raw skim milk		1.034	17.8	.2352	0.1671	0.0185
Serum:						
First day—3 hours	34.3	1.023		.0753	.0450	.0133
First day—next 18 hours	81.5	1.025	8.8	.1029	.0554	.0133
Second day	109.8	1.025	9.0	.1054	.0581	.0134
Do				.1055	.0588	.0133
Third day	109.3	1.025	9.0	.1055	.0578	.0127
Fourth day	112.0	1.025	9.0	.1048	.0585	.0127
Fifth day	105.7	1.025	9.0	.1054	.0589	.0130
Sixth and seventh days	205.0	1.025	9.0	.1057	.0579	.0129
Do				.1053	.0582	.0131
Tenth and eleventh days	155.0	1.025	10.0	.1074	.0609	.0131
Thirteenth and fourteenth days	158.5	1.025	12.0	.1082	.0633	.0139
Fifteenth and part of sixteenth day	105.0		14.6	.1110	.0683	.0145

[1] Number of cubic centimeters of $\frac{N}{10}$ alkali required to neutralize 100 c. c. of serum.

As will be seen from the above table there is an absorption of both phosphoric acid and calcium at the beginning of filtration, while the magnesium passes completely through the cell wall. For this reason the first portion of the serum must be rejected as worthless for making comparisons. The quantity to be rejected varies with the size of the cell used and may amount to from 60 to 90 c. c.

The specific gravity of the serum collected during the first 3 hours was 1.023, and it increased to 1.025 during the next 18 hours, after which time it remained constant during the remainder of the experiment.

The acidity was 8.8 on the first day and 9 on the second day. After the ninth day the acidity began to increase gradually, being 10 on the tenth and eleventh days, while on the fifteenth day it was 14.6, showing that the lactic acid had considerably increased.

The phosphoric acid during the first 3 hours amounted to only 0.0753 per cent, and it increased to 0.1029 per cent during the next 18 hours. On the second day it was 0.1054 per cent, and then remained constant until the tenth and eleventh days, when it began gradually to increase, amounting to 0.1110 per cent on the fifteenth day.

The calcium content was also low during the first 3 hours of filtration, amounting to 0.045 per cent, and it increased to 0.0554 per cent during the next 18 hours. On the second day it was 0.0581 per cent, and began to increase gradually as the acidity increased, amounting to 0.0683 per cent on the fifteenth day.

The magnesium remained constant during the first 11 days and then increased very slowly up to the fifteenth day.

The experiment shows, furthermore, that the filtration of a clean milk with low bacterial count can be continued for about one week without any appreciable chemical changes taking place in the serum, provided the temperature be kept at 6° to 8° C. (42.8° to 46.4° F.).

Before proceeding to the filtration of raw milk in the refrigerator, several experiments were made in which formaldehyde had been added to the milk as a preservative. This was done in order to carry on the filtration at room temperature. The results obtained showed that the serum, after the first day's filtration, remained of constant composition, and led up to carrying out the filtration of a pure milk in the refrigerator.

Having thus shown that the serum remains of constant composition after the first day of filtration, the next step was to determine whether there were any demonstrable changes produced in the soluble phosphates by pasteurization. In order to produce a maximum precipitation the highest temperature, 68.3° C. (155° F.), employed in the holder process was chosen. The results obtained are shown in Table 2.

TABLE 2.—*Quantity of soluble phosphates in the serum of raw whole milk and in whole milk pasteurized at 68.3° C. (155° F.) for 30 minutes.*

	Specific gravity.	Acidity.	P_2O_5.	CaO.	MgO.
			Per cent.	*Per cent.*	*Per cent.*
Casein			0.0595		
Raw whole milk	1.029	18.0	.2219	0.1749	0.0203
Raw serum:					
Second and third days	1.026	9.8	.1074	.0625	.0142
Do			.1078	.0624	.0142
Fifth and sixth days	1.026	9.6	.1082	.0631	.0143
Pasteurized serum:					
Second and third days	1.026	9.6	.1078	.0611	.0140
Do			.1063	.0613	.0140
Fifth and sixth days	1.026	9.4	.1089	.0627	.0141

It will be seen from the table that the changes produced by pasteurization at 68.3° C. (155° F.) for 30 minutes are trifling. The phosphoric acid content remains the same in both the raw and the pasteurized serum. The quantity of lime salts, while a trifle lower in the pasteurized than in the raw serum, is still within the limit of error, and the magnesia remains the same in both serums.

Other experiments made with skim milk showed results agreeing in every particular with this one made with whole milk. All preliminary experiments were made with skim milk because, as previously stated, it filters more readily and thus gives a larger quantity of serum for analysis.

Comparing Table 1 with Table 2 we find that the variation in the quantity of soluble lime salts between the two samples of milk is far greater than that found between the raw and pasteurized serums. For this reason the objection frequently raised against pasteurized milk as an infant food, on the ground that the soluble lime salts are diminished by the process of pasteurization, is without foundation.

CHEMICAL CHANGES IN THE PROTEINS.

LACTALBUMIN.

Different investigators do not agree as to the exact temperature at which the coagulation of the albumin begins. Steiner [1] found no change on heating milk for 25 minutes at 60° C. (140° F.), while Solomin [2] says that the change seems to begin at this temperature, and Jensen and Plattner [3] also found some coagulation in milk heated for five hours at 60° C. (140° F.). Babcock [4] could find no change on heating milk for 20 minutes at 65° C. (149° F.), while Woll [5] states that coagulation begins at this temperature. According to Willoughby [6] the change begins at 70° C. (158° F.), while de Freudenreich [7] found 15 to 20 per cent coagulated on heating milk for 30 minutes at 68° to 69.5° C. (154.4° to 157° F.). A series of experiments were therefore undertaken to determine at what temperature the change in the albumin begins, and to what extent it is coagulated at the different temperatures commonly employed in the pasteurization of milk.

METHODS OF ANALYSIS.

Casein.—To 10 grams of milk were added 50 c. c. of distilled water at 40° C. (104° F.), then 1.5 to 2 c. c. of a saturated alum solution were added gradually. The precipitate was allowed to settle, was then filtered and washed. The precipitate and filter paper were treated by the Gunning method, adding about 0.2 gram of copper sulphate.

Albumin and globulin.—The albumin and globulin in the filtrate and washings were precipitated with 10 c. c. of Almén's tannin solution; this was allowed to settle, was then filtered and washed. The precipitate was treated the same as under casein.

Tables 3 to 6 show the results of the experiments to determine the lactalbumin precipitated in whole milk pasteurized for 30 minutes at temperatures ranging from 62.8° C. (145° F.) to 71.1° C. (160 F.).

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[1] Steiner, R. Beiträge zur Kenntnis des Einflusses der Pasteurisierung auf die Beschaffenheit der Milch und auf den Butterungs Prozesz. Milch-Zeitung, vol. 30, no. 26, p. 401–403, June 29; no. 28, p. 435, July 13. Leipsic, 1901.

[2] Solomin, P. Ueber die beim Erhitzen der Milch ausfallenden Eiweissmengen. Archiv für Hygiene, vol. 28, no. 1, p. 43–48. Munich and Leipsic, 1896.

[3] Jensen, Orla, and Plattner, Ernest. De l'action du chauffage sur le lait de vache. Revue Générale du Lait, vol. 4, no. 16, p. 361–368, May 30; no. 17, p. 388–397, June 15; no. 18, p. 419–424. Lierre, 1905.

[4] Babcock, S. M. The centrifugal separation of casein and insoluble phosphates from milk. Wisconsin Agricultural Experiment Station, Twelfth Annual Report (1895), p. 93–99. Madison, 1896.

[5] Woll, F. W. The effect of pasteurization and sterilization on the viscosity and fat globules of milk and cream. Wisconsin Agricultural Experiment Station, Twelfth Annual Report (1895), p. 164–173. Madison, 1896.

[6] Willoughby, Edward F. Milk, its production and uses. London, 1903. See p. 125–126.

[7] De Freudenreich, Ed. Sur la pasteurisation du lait dans l'alimentation de l'enfance. Revue Générale du Lait, vol. 4, no. 19, p. 433–437. Lierre, July 15, 1905.

TABLE 3.—*Quantity of albumin precipitated in raw whole milk and in milk pasteurized at 62.8° C. (145° F.) for 30 minutes.*

	Raw milk.			Pasteurized milk.		
	I.	II.	Average.	I.	II.	Average.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Casein nitrogen	0.4003	0.4027	0.4015	0.4015	0.4010	0.4013
Albumin+globulin nitrogen	.0996	.0998	.0997	.0996	.0997	.0997
PROTEIN=NITROGEN×6.38.						
Casein	2.554	2.569	2.562	2.561	2.558	2.560
Albumin+globulin	.635	.637	.636	.635	.636	.636

No albumin precipitated.

TABLE 4.—*Quantity of albumin precipitated in raw whole milk and in milk pasteurized at 65.6° C. (150° F.) for 30 minutes.*

	Raw milk.			Pasteurized milk.		
	I.	II.	Average.	I.	II.	Average.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Casein nitrogen	0.4260	0.4218	0.4239	0.4320	0.4328	0.4324
Albumin+globulin nitrogen	.0983	.0978	.0981	.0920	.0929	.0925
PROTEIN=NITROGEN×6.38.						
Casein	2.717	2.691	2.704	2.756	2.762	2.759
Albumin+globulin	.627	.624	.626	.587	.593	.590

Albumin precipitated=5.75 per cent.

TABLE 5.—*Quantity of albumin precipitated in raw whole milk and in milk pasteurized at 68.3° C. (155° F.) for 30 minutes.*

	Raw milk.			Pasteurized milk.		
	I.	II.	Average.	I.	II.	Average.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Casein nitrogen	0.3739	0.3812	0.3776	0.3910	0.3878	0.3894
Albumin+globulin nitrogen	.0963	.0981	.0972	.0863	.0833	.0848
PROTEIN=NITROGEN×6.38.						
Casein	2.385	2.432	2.409	2.495	2.474	2.485
Albumin+globulin	.614	.626	.620	.551	.531	.541

Albumin precipitated=12.75 per cent.

TABLE 6.—*Quantity of albumin precipitated in raw whole milk and in milk pasteurized at 71.1° C. (160° F.) for 30 minutes.*

	Raw milk.			Pasteurized milk.		
	I.	II.	Average.	I.	II.	Average.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Casein nitrogen	0.3860	0.3851	0.3856	0.4200	0.4169	0.4185
Albumin+globulin nitrogen	.0961	.0989	.0975	.0681	.0667	.0674
PROTEIN=NITROGEN×6.38.						
Casein	2.462	2.457	2.460	2.679	2.660	2.670
Albumin+globulin	.613	.631	.622	.434	.426	.430

Albumin precipitated=30.87 per cent.

From an analysis of the above tables it is apparent that no albumin is coagulated on heating milk for 30 minutes at 62.8° C. (145° F.), the temperature most commonly used in the holder process in commercial pasteurization. At 65.6° C. (150° F.) the separation of the albumin has begun, 5.71 per cent having become insoluble. At 68.3° C. (155° F.) the quantity has increased to 12.76 per cent, while at 71.1° C. (160° F.) 30.87 per cent of the albumin has been coagulated.

CASEIN.

The condition in which casein exists in milk has not as yet been fully explained. The effect of heat shows itself in two ways. In the first place, the rennin coagulation may be accelerated, retarded, or even inhibited; and in the second place, the coagulum may assume a different character from that obtained from raw milk.

The great majority of authors agree that no change in rennin coagulation takes place below 65° C. (149° F.). Steiner[1] found a retardation in milk heated to 60° C. (140° F.), while Fleischmann and Morgen[2] found the milk less sensitive to rennin when heated for two hours from 60° to 70° C. (140° to 158° F.). According to Van Slyke and Publow[3] milk heated above 65.6° C. (150° F.) for a considerable length of time coagulates less rapidly and the coagulum is highly flocculent. De Freudenreich[1] finds the coagulum unchanged at 68° to 69.5° C. (154.4° to 157.1° F.). Jensen and Plattner[1] state that retardation begins on heating milk for five hours at 70° C. (158° F.), while Mayer[4] places the beginning at 75° C. (167° F.). Stassano and

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[1] Loc. cit.

[2] Fleischmann, W., and Morgen, A. Einiges über die nach Scherff's Verfahren conservirte Flaschen milch. Die Landwirthschaftlichen Versuch Stationen, vol. 28, p. 321–332. Berlin, 1883.

[3] Van Slyke, Lucius L., and Publow, Charles A. The science and practice of cheese-making, p. 310. New York, 1909.

[4] Mayer, Adolf. Bestimmungen der Wirksamkeit des Labfermentes unter verschiedenen äusseren Umständen. Milch-Zeitung, vol. 10, no. 2, p. 17–19, Jan. 12; no. 3, p. 33–38, Jan. 19; no. 4, p. 49–52, Jan. 26; no. 6, p. 81–84, Feb. 9. Bremen, 1881.

Talarico[1] differ from all the preceding in that they observed an acceleration of rennin coagulation in milk heated from 55° to 65° C. (131° to 149° F.), while at 70° C. (158° F.) the heated milk behaved the same as raw milk, and above 70° C. (158° F.) the retardation began.

The following experiments were made with raw milk and milk pasteurized at various temperatures:

METHOD OF COAGULATION.

The apparatus consisted of a large galvanized-iron box having four cylindrical compartments surrounded by water. The upper openings were of sufficient size to admit a cylindrical percolater (1 foot high and 2½ inches in diameter), the lower openings being about one-fourth of an inch in diameter. A small glass tube drawn out into a capillary was inserted into the neck of the percolator by means of a perforated rubber stopper.

In making the test, the water in the box was heated to the required temperature, the percolators were then placed in the compartments and allowed to remain until they had acquired the temperature of the bath, the upper openings being covered. Next 200 c. c. of milk were heated, the rennin solution added, and, after mixing, poured into the percolator. The upper opening was then closed with a cover and the time required for the milk to coagulate in the tube noted. The flow through the tube was regulated by breaking off the capillary to such an extent that all tubes dropped at the same rate.

For each experiment 200 c. c. of milk were heated in an Erlenmeyer flask to 35° C. (95° F.) and 5 c. c. of rennin solution (0.15: 100 c. c. of water) added. This was taken as the beginning of the coagulation time; the end point was when the milk stopped dropping from the capillary tube. The rennin solution was made of such strength that the raw milk coagulated in about 20 minutes. The results are shown in the following table:

TABLE 7.—*Time required for rennin coagulation of raw whole milk and of whole milk pasteurized at different temperatures. Milk 200 c. c., rennin solution (0.15 gram: 100 c. c. of water) 5 c. c.*

Experiment.	Raw milk.	Milk pasteurized at—				
		55° C. (131° F.).	60° C. (140° F.).	65° C. (149° F.).	70° C. (158° F.).	75° C. (167° F.).
	M. s.	*M. s.*	*M. s.*	*M. s.*	*M. s.*	*M. s.*
I.	18 30	17 28	17 10	17 12		
	18 08	16 56	16 53	17 12		
II.	19 34				20 38	36 30
	19 23				20 25	37 30

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[1] Stassano, H., and Talarico, J. De l'influence de la cuisson sur la caséification du lait par le lab-ferment. Comptes Rendus Hebdomadaires des Séances et Mémoires de la Société de Biologie, vol. 69 (année 62, tome 2), no. 28, p. 254–255. Paris, Aug. 5, 1910.

From the above table it will be seen that milk pasteurized at 55° C. (131° F.), 60° C. (140° F.), and 65° C. (149° F.) all coagulate more rapidly with rennin than does the raw milk. This result was obtained in all cases in a large number of experiments. At 70° C. (158° F.) the retardation of rennin coagulation has begun, while at 75° C. (167° F.) the time has about doubled and the coagulum is highly flocculent.

CHANGES IN THE ACIDITY.

Woll[1] and de Freudenreich[1] find no appreciable change in the acidity of milk pasteurized at 67° to 68° C. (153° to 154.4° F.) for 20 minutes. Höft[2] and Jensen and Plattner[1] on the other hand find a diminution in the acidity on heating milk.

From a large number of experiments made during the coagulation of milk by rennin, it was found that the acidity of the milk always diminished during pasteurization. While the diminution was slight it amounted to several tenths of a cubic centimeter, and was always sufficient to be determined by titration with tenth-normal caustic-soda solution. The diminution, however, is insignificant and is probably due to a loss of carbonic acid during the heating. Furthermore, the diminution varies in different samples of milk.

SUMMARY AND CONCLUSIONS.

1. Milk pasteurized by the holder process at 62.8° C. (145° F.) for 30 minutes does not undergo any appreciable chemical change.

2. The soluble phosphates of lime and magnesia do not become insoluble. At 68.3° C. (155° F.) the quantity of phosphoric acid, lime, and magnesia in the serum of both raw and pasteurized milk are practically the same.

3. The albumin does not coagulate at 62.8° C. (145° F.), but at 65.6° C. (150° F.) 5.75 per cent of the albumin is rendered insoluble. As the temperature increases the amount of coagulated albumin increases. At 68.3° C. (155° F.) the quantity increases to 12.75 per cent, and at 71.1° C. (160° F.) it amounts to 30.78 per cent.

4. The time required for coagulating the casein by rennin is slightly less in milk pasteurized at temperatures up to 65° C. (149° F.) than it is in raw milk. At 70° C. (158° F.) there is a slight retardation, while at 75° C. (167° F.) the time has almost doubled.

5. The acidity as determined by titration is slightly diminished in pasteurized milk.

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[1] Loc. cit.

[2] Höft, H. Ueber die Veränderung der Acidität der Milch beim Erhitzen. Milch-Zeitung, vol. 30, no. 7, p. 103. Leipzig, Feb. 16, 1901.

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BUREAU OF ANIMAL INDUSTRY.—BULLETIN [illegible]

A. D. MELVIN, CHIEF OF BUREAU.

2. 60

THE ACTION OF ARSENICAL DIPS IN PROTECTING CATTLE FROM INFESTATION WITH TICKS.

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THE ACTION OF ARSENICAL DIPS IN PROTECTING CATTLE FROM INFESTATION WITH TICKS.

SUMMARY.

In this bulletin the factors entering into the efficacy of dips used against ticks are discussed. Dips act both in a direct destructive way and in a protective manner preventing infestation. The protective action of a dip may be in the nature of a destructive or of a repellent action. The influence of dips on oviposition and the viability of the eggs is a factor in efficacy.

The ingredients of homemade arsenical dips and the known or probable functions of each ingredient are discussed.

It is suggested herein that any protective action that the usual arsenical dips might have would be expected to be due to a toxic rather than to a repellent action. Watkins-Pitchford has shown that cattle dipped in arsenic are poisonous to ticks.

Ticks are destroyed by dips either by suffocation or by poisoning, or by both means. Tests were conducted showing that ticks are suffocated by the closing of the respiratory openings (spiracles). It was found that practically all engorged females that had their spiracles closed with Canada balsam died. In other tests of the same sort, in which oils were used, Beaumont oil proved much less effective than Canada balsam, and cottonseed oil was practically without effect.

Smearing the scutum and mouth parts of engorged females with oils and viscous substances had no influence on the mortality, or oviposition, or on the per cent of eggs hatching.

In tests in which engorged females were dipped in Beaumont oil and in cottonseed oil the former proved very much more effective than the latter, and this is due in all probability to a toxic action. Beaumont oil had a marked influence on oviposition, on the number of eggs deposited, and on the viability of the eggs, whereas cottonseed oil had no effect.

The possible avenues for the entrance of arsenic into the bodies of ticks are enumerated, and the porose areas are pointed out as possible vulnerable points in the armor of the tick.

Three cattle-dipping experiments were conducted with an arsenical dip containing 8 pounds of arsenic trioxid to 500 gallons of water, in order to test its protective action against tick infestation. Seed ticks were placed on the cattle at varying periods after they were dipped. In the first experiment the ticks were placed on the cattle at periods ranging from a few hours to four weeks, in the second from a few hours to two days, and in the third at five days after dipping. It was found that the dip rendered no protection when the exposure to infestation was five days or longer after dipping. The limit of protection ascertained in the experiments was two days. No tests were made covering the intervening period between two and five days.

Arsenical poisoning which occurred among the animals in one experiment was apparently caused by undissolved arsenic in the dip. It would therefore seem that undissolved arsenic in a dip is highly dangerous.

It is shown conclusively that the protective action of arsenic is dependent on its toxic action, and not on a repellent action.

As a result of incidental observations made on engorged female ticks from animals suffering from Texas fever it was found that the mortality of such ticks may be very high, as much as 95 per cent. The cause for this is not known. It may be nutritional in character, due to the changed or impoverished condition of the blood absorbed, or it may be due to the parasitism of *Piroplasma bigeminum*, the microorganism which is the direct cause of Texas fever.

Observations made for the purpose of determining whether there was any relationship between the degree of infestation and the time elapsing between the last dipping and the infestation, and also on the mortality of engorged females from dipped animals infested subsequently to dipping, as compared with that of ticks from undipped animals, were inconclusive. Oviposition and viability of the eggs of these ticks appeared to be unaffected.

INTRODUCTION.

The efficacy of a dip used against such a pest as the cattle tick may be considered under two heads, namely, its direct destructive action, and its protective action in preventing reinfestation. (Protective action may be the result either of a destructive or of a repellent action, or of both.) These properties are no doubt combined to a certain degree in all dips that have proved effective against ticks. The relative importance that they assume, from a practical standpoint, depends on the particular purpose for which dipping is done. If it is desired to render cattle free of ticks, and they are not to be subjected to the dangers of reinfestation, the protective value of the dip is of minor importance. On the other hand, if the purpose is to eradicate the ticks from a given area, and the animals are turned back on infested fields subsequent to each treatment, the protective value of a dip assumes considerable importance. In the former case the protective properties would be of value only in case the animals should by accident be subjected to infestation subsequent to dipping, whereas in the latter case they would play an important part in bringing about extermination. It is conceivable, though we have no such dips at present, that a dip might stand low in its direct destructive action and still prove highly effective in eradication work because of its protective (repellent) properties.

In addition to the destructive and protective qualities of a dip another factor must be considered, and that is its influence on oviposition and on the viability of the eggs deposited. It has been pointed out in Bulletin 144 of the Bureau of Animal Industry that arsenic diminishes both the number of eggs deposited by females that survive and to a marked degree the viability of the eggs. Certain oils also affect the number of eggs deposited and the viability of the eggs. Various oils are known to be more or less effective against ticks, and they all no doubt possess a certain amount of protective value, dependent on their odor, their disagreeable nature, or the destructive action they exert when seed ticks come in contact with them. Other things being equal, the less volatile the oil the longer the protective action lasts.

The arsenical dips which have shown a high degree of efficacy against ticks were commonly supposed to have little or no protective value until Watkins-Pitchford[1] in 1910 showed by experiments that animals dipped in arsenic are poisonous to ticks. The same author[2] in other experiments found that 16.8 per cent of the adult ticks that became attached to cattle shortly after dipping in arsenic (4 pounds of arsenite of soda (80 per cent arsenic), 3 pounds of soft soap, and 1 gallon of paraffin to make 400 gallons of dip) were dead at the end of three days, and that in the case of horses 22.5 per cent of the ticks were dead. In one experiment in which horses had been frequently dipped the tick mortality was 36.8 per cent among ticks that attached during the course of three days.

Arsenical dips containing sodium metarsenite in alkaline solution and an admixture of pine tar could not be expected to exert any repellent action because of their physical nature or their odor, except in so far as the tar is concerned, the action of which, however, must be very slight. Any protective value that such dips have, therefore, must necessarily depend largely on the toxicity of the arsenic present on or in the skin of dipped animals. Watkins-Pitchford[2] found that the arsenical dip above mentioned retarded infestation with larvæ and nymphs of the brown tick. The time between treatment and infestation is not stated, but it was presumably only a few hours. The author attributed the protective action to the paraffin component of the dip. It was found that dipping did not hinder infestation with the adult of the brown tick, but that the number on cattle subjected to infestation rapidly decreased as a result of the poisonous effect of the arsenic present in the skin of the animals.

In the work of tick suppression and tick eradication in this and other countries arsenical dips have proved satisfactory when used at regular intervals. The strength of the dip and the interval between treatments have been determined with a view of obtaining the best results with as little injury to the cattle as possible. The interval between dippings has rested largely on an empirical basis, except in the case of treatment directed against certain species of ticks of economic importance in South Africa that drop from their host previous to each molt, in which case the period has been based in some instances on the minimum time the tick has been found to remain attached to the host. Little is known as to how much the arsenical dip plays in a protective way in bringing about the results that have been attained. It was with a view of determining to what extent and for how long arsenic protects against infestation that the experiments detailed in this paper were taken up.

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[1] Natal Agricultural Journal, Pietermaritzburg, vol. 15, no. 3, Sept., 1910, pp. 312–328.

[2] Agricultural Journal, Union of South Africa, Pretoria, vol. 2, no. 1, July, 1911, pp. 33–79. Rhodesia Agricultural Journal, Salisbury, vol. 10, no. 3, Feb., 1912, pp. 372–400.

COMPOSITION OF ARSENICAL DIPS.

Arsenic seems to have almost a specific action on ticks. The arsenical dips in use against ticks as a rule have their arsenic present in the form of sodium or potassium metarsenite, the former of which, however, in the presence of bacterial growth, as shown by Fuller,[1] gradually becomes oxidized to the arsenate. In the home-made dips used in this country the only other ingredients are an excess of sodium carbonate and pine tar. In formulas that were formerly tried in this country, and some now in use in other countries, there are other ingredients, such as soap and emulsified paraffin (kerosene).

Watkins-Pitchford[2] has found that paraffin emulsified with soap in the dip ameliorates its irritative action and that the addition of emulsified paraffin and glycerin subdues this action still more. It is not likely that the soap, pine tar, or paraffin exert any important destructive action on ticks, especially in view of the fact that they constitute less than 1 per cent of the dip. Watkins-Pitchford[3] found that the mortality of ticks in the case of two arsenical dips was raised 1.8 and 5.7 per cent by the addition of soap and paraffin. His observations, however, were based on too small a number of ticks to be considered conclusive. All three of the ingredients mentioned may serve a certain function in causing the arsenic to adhere more tenaciously to the skin and hair, and the tar and paraffin may exert a slight amount of repellent action because of their odor and physical properties. They also serve the purpose of giving the dip a distinctive character. The soap serves a function in the emulsification of the tar or kerosene, depending on which is used, and probably exerts a certain amount of cleansing effect on the skin.

The excess of sodium carbonate in the two formulas in use in this country, in which 8 and 10 pounds of white arsenic are used to 24 and 25 pounds, respectively, of sodium carbonate, is considerable. Whereas only 1.45 parts by weight of sodium carbonate to 1 part of arsenic are necessary in the formation of sodium metarsenite, in the above formulas 2½ to 3 parts are used to each part of arsenic. However, this excess of sodium carbonate serves a number of important purposes. It facilitates the solution of the arsenic, aids in the emulsification of the tar, cleanses the skin of the cattle, and possibly softens the cuticle of the ticks and thus facilitates the entrance of arsenic.

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[1] Circular 182, Bureau Animal Industry, U. S. Department of Agriculture. Washington, 1911.

[2] Natal Agricultural Journal, Pietermaritzburg, vol. 12, no. 4, Apr. 30, 1909.

[3] Agricultural Journal, Union of South Africa, Pretoria, vol. 2, no. 1, July, 1911, pp. 33–79. Rhodesia Agricultural Journal, Salisbury, vol. 10, no. 3, Feb., 1912, pp. 372–400.

THE MANNER IN WHICH DIPS ACT ON TICKS.

When ticks are destroyed by a dip they are killed by suffocation, by being poisoned, or by a combination of both causes. In the case of the use of such substances as oils it is probable that death is due both to suffocation and to a toxic action.

THE ACTION OF OILS AND OTHER SUBSTANCES ON TICKS.

SMEARING THE SPIRACLES.

That ticks may be suffocated the writer has shown by closing the spiracles of engorged females of the cattle tick with Canada balsam. On May 19, 1911, 10 engorged females that had already begun to oviposit had their spiracles closed with a drop of balsam. On the following day the ticks were normal in color but were inactive, their legs being stretched out straight. On the third day all the ticks had turned dark and were dead. No eggs were deposited. In the control lot of 10 ticks 4 died. Many eggs were deposited, 40 per cent of which hatched.

In order to determine whether the xylol in the balsam may not have played a part in the destruction of the ticks a second test was made on May 26 in which the spiracles of 10 engorged females that had begun to oviposit were touched with xylol. One tick turned dark. All oviposited, and a normal number of eggs were deposited, about 30 per cent of which hatched.

On September 27, 1912, another lot of 20 engorged females just collected had their spiracles touched with Canada balsam. On September 30 all of them were dead. In two control lots of 20 engorged females each, collected on the same date, all the ticks remained normal and oviposited; 92 and 60 per cent of the eggs hatched.

On September 29, 1912, a third lot of 20 engorged females, collected on September 27, 1912, had their spiracles touched with Canada balsam. Seventeen of the ticks were killed, the remainder deposited normal eggs. Eighty-seven per cent of the eggs hatched. In two control lots of 20 ticks each, collected on the same date as the above lot, all oviposited and a usual number of normal eggs were deposited; 92 and 80 per cent of the eggs hatched.

From the above tests it may be definitely concluded that a complete closing of the spiracles of engorged females will lead to their destruction. In the case of the three ticks in the last lot that survived it seems safe to assume, in view of the number of positive tests, that the spiracles were not completely closed.

Some additional tests were made along the above line with other oils. On May 13, 1911, eight engorged females that had already begun to oviposit had their spiracles smeared with Beaumont crude petroleum. All but one continued oviposition. Three of the ticks died. Many eggs were deposited, 25 per cent of which hatched. In a control lot of seven ticks all continued oviposition. Four ticks died. A fair number of eggs were deposited, about 30 per cent of which hatched.

September 27, 1912, 20 engorged females collected on that date had their spiracles touched with crude Beaumont oil. One (5 per cent) of the ticks died. It had apparently been injured about the head when removed from the host. Three ticks remained plump. Nineteen ticks oviposited, and a normal number of eggs were produced. Seven per cent of the eggs hatched.

September 27, 1912, 20 engorged females just collected had their spiracles touched with refined cottonseed oil. None died. All oviposited, and a normal number of eggs were deposited. Ninety-two per cent of the eggs hatched.

Two control lots of 20 ticks each, collected on the same date as the above, remained normal. All the ticks oviposited, and a normal number of eggs were produced; 92 and 60 per cent of the eggs hatched.

On September 27, 1912, 20 engorged females just collected had their spiracles touched with Beaumont oil. One (5 per cent) failed to oviposit. Three (15 per cent) died. A normal number of eggs were deposited. Twenty per cent of the eggs hatched.

On September 28, 1912, 20 ticks collected on September 27 had their spiracles touched with refined cottonseed oil. None of the ticks died. All the ticks oviposited, and a normal number of eggs were deposited. Ninety per cent of the eggs hatched.

In two control lots of 20 ticks each, collected on the same date as the above, none died, and all oviposited, a normal number of eggs being produced; 80 and 92 per cent of the eggs hatched.

On May 26, 1911, 10 engorged females that had begun to oviposit had their spiracles touched with pine tar. All oviposited, and a normal number of eggs were deposited, 15 per cent of which hatched. In the control lot of 10 ticks, all but one oviposited, and five died without completing oviposition. Many eggs were deposited, 10 per cent of which hatched.

Summary of tests in which spiracles of engorged females were smeared with oil.

Date of experiment.	Mortality.	Ticks ovipositing.	Number of eggs deposited.	Eggs hatched.	Substance used.
	Per cent.	*Per cent.*		*Per cent.*	
May 13, 1911	38	88	Many	25	Beaumont oil.
Do	57	100	Fair	30	(Control.)
Sept. 27, 1912	5	95	Normal	7	Beaumont oil.
Do	0	100	do	92	Cottonseed oil.
Do	0	100	do	92	(Control.)
Do	0	100	do	60	Do.
Do	15	95	do	20	Beaumont oil.
Sept. 28, 1912	0	100	do	90	Cottonseed oil.
Sept. 27, 1912	0	100	do	80	(Control.)
Do	0	100	do	92	Do.
May 26, 1911		100	do	15	Pine tar.
Do	50	90	Many	10	(Control.)

It is noted from the above table that the mortality of the different lots of ticks treated with Beaumont oil compared with that of the corresponding controls is as follows: 38 per cent, control 57 per cent; 5 per cent, controls 0 per cent; 15 per cent, controls 0 per cent. This indicates a detrimental effect of the Beaumont oil, but is in marked contrast with the results obtained when the spiracles were closed with Canada balsam, in which case the mortality was practically 100 per cent. The mortality in the case of cottonseed oil was 0. Beaumont oil, therefore, appears to be much more effective than cottonseed oil in closing the spiracles, although it should be borne in mind that there may be a toxic effect that entered into the results. It is evident that Beaumont oil does not close the spiracles as effectually as Canada balsam.

The percentage of ticks in the lots treated with Beaumont oil that oviposited, compared with the percentage in the corresponding controls, is as follows: 88 per cent, control 100 per cent; 95 per cent, controls 100 per cent; 95 per cent, controls 100 per cent. It appears from this that the treatment had a slight effect on oviposition. Cottonseed oil had no effect on the percentage ovipositing. The treatment in no case had any effect on the number of eggs deposited. The percentage of eggs that hatched in the case of the ticks treated with Beaumont oil, compared with the percentage in the corresponding control lots, is as follows: 25 per cent, control 30 per cent; 7 per cent, controls 60 and 92 per cent; and 20 per cent, controls 80 and 92 per cent. From this it appears that the Beaumont oil applied to the spiracles must have been absorbed to some extent and by this means exerted a detrimental influence on the eggs.

The percentage of eggs hatching in the case of ticks treated with cottonseed oil, compared with that of the corresponding controls, is as follows: 92 per cent, controls 60 and 92 per cent; and 90 per cent, controls 80 to 92 per cent. It is therefore noted that cottonseed oil had no influence on the eggs.

SMEARING THE SCUTUM AND MOUTH PARTS.

In order to determine whether the presence of an oil or viscous substance on the scutum and mouth parts would interfere with oviposition and the laying of normal eggs, a number of tests were made. On June 8, 1911, 10 engorged females that had already begun to oviposit were smeared on the scutum and mouth parts with Beaumont oil. Eight of the ticks died. All but one of the ticks deposited some eggs. Only a few eggs were deposited, none of which hatched. In the control lot of 10 ticks, 6 died. All oviposited. A moderate number of eggs were deposited, none of which hatched.

On June 8, 1911, 10 engorged ticks that had begun to oviposit were similarly smeared with Canada balsam. All but one oviposited. Eight ticks died. A moderate number of eggs were deposited, less than 1 per cent of which hatched. In the control lot of ticks, six died. All oviposited. A moderate number of eggs were deposited, none of which hatched.

On June 8, 1911, 10 engorged females that had begun to oviposit were smeared on the scutum and mouth parts with pine tar. All the ticks oviposited. Eight died. A considerable number of eggs were deposited, 10 per cent of which hatched. In the control lot, consisting of 10 ticks, 6 died. All oviposited. A moderate number of eggs were deposited, none of which hatched.

September 27, 1912, 20 engorged females just collected were similarly smeared with crude Beaumont oil. All oviposited. A normal number of eggs were deposited. Fifty per cent of the eggs hatched.

On September 27, 1912, 20 engorged females just collected were smeared on the scutum and mouth parts with refined cottonseed oil. One tick became discolored. Two more ticks became discolored shortly before oviposition was completed. All oviposited. A normal number of eggs were deposited, and 87 per cent of the eggs hatched.

On September 27, 1912, 20 engorged females just collected were similarly smeared with Canada balsam. All oviposited. A usual number of normal eggs were deposited. Seventy-five per cent of the eggs hatched.

In two control lots of 20 ticks each, collected on the same date as the above, none died. All oviposited. A normal number of eggs were deposited; 92 and 60 per cent of the eggs hatched.

On September 27, 1912, the scutum and mouth parts of 20 engorged females just collected were smeared with crude Beaumont oil. One tick (5 per cent) died and one became abnormal in appearance. All but one oviposited. A normal number of eggs were deposited. Eighty-five per cent of the eggs hatched.

On September 28, 1912, the scutum and mouth parts of 20 engorged females collected on the previous day were smeared with refined cottonseed oil. Five ticks (25 per cent) died. Sixteen ticks oviposited. A normal number of eggs were deposited. Ninety-five per cent of the eggs hatched.

September 29, 1912, the scutum and mouth parts of 20 engorged females collected on September 27 were smeared with Canada balsam. All the ticks lived and oviposited. A usual number of normal eggs were deposited. Fifty per cent of the eggs hatched.

In two control lots of 20 ticks each, collected on the same date as the above, none died. All oviposited and a normal number of eggs were deposited; 92 and 80 per cent of the eggs hatched.

Summary of tests in which the scutum and mouth parts of engorged females were smeared with oils.

Date of test.	Mortality.	Ticks ovipositing.	Number of eggs deposited.	Eggs hatched.	Substance used.
1911.	*Per cent.*	*Per cent.*		*Per cent.*	
June 8	80	90	A few	0	Beaumont oil.
Do	60	100	Moderate	0	(Control.)
Do	80	90	do	(1)	Canada balsam.
Do	60	100	do	0	(Control.)
Do	80	100	Considerable	10	Pine tar.
Do	60	100	Moderate	0	(Control.)
1912.					
September 27	....	100	Normal	50	Beaumont oil.
Do	[2] 0	100	do	87	Cottonseed oil.
Do	0	100	do	75	Canada balsam.
Do	0	100	do	92	(Control.)
Do	0	100	do	60	Do.
Do	[3] 5	95	do	85	Beaumont oil.
September 28	25	80	do	95	Cottonseed oil.
September 29	0	100	do	50	Canada balsam.
September 27	0	100	do	92	(Control.)
Do	0	100	do	80	Do.

[1] Less than 1 per cent.
[2] Three (15 per cent) became discolored.
[3] One more (5 per cent) became abnormal in appearance.

In the tests in the above table, started on June 8, 1911, the high mortality of the ticks was no doubt due to the fact that they had been sent in from the South and in consequence had been injured to a certain extent. A comparison of the mortality of the treated ticks with that of the corresponding controls indicates that the treatment played no important part, if any, in determining the percentage of mortality. It is likewise apparent that the treatment had practically no influence on the number ovipositing and on the number of eggs deposited, and, so far as can be determined, the same seems to be true with regard to the viability of the eggs.

DIPPING THE TICKS IN OILS.

A number of tests were made in which ticks were dipped in crude Beaumont oil and in refined cottonseed oil.

On September 27, 1912, 20 engorged females just collected were dipped in crude Beaumont oil. Eleven (12?) oviposited. Eight

(40 per cent) died. Only a small number of eggs were deposited, part of which shriveled. Less than 1 per cent of the eggs hatched.

On September 27, 1912, 20 engorged females just collected were dipped in refined cottonseed oil. One tick (5 per cent) died. All oviposited. A normal number of eggs were deposited. Ninety per cent of the eggs hatched.

In two control lots collected on September 27, consisting of 20 ticks each, none died. All oviposited and a normal number of eggs were deposited; 92 and 60 per cent of the eggs hatched.

September 27, 1912, 20 engorged females just collected were dipped in Beaumont crude petroleum. Thirteen ticks (65 per cent) oviposited. Eight ticks (40 per cent) died. Several others became abnormal in appearance. Only a few eggs were deposited, about half of which shriveled. Less than 1 per cent of the eggs hatched.

September 28, 1912, 20 engorged females collected the previous day were dipped in refined cottonseed oil. All but one tick remained normal. A normal number of eggs were deposited, some of which shriveled. Eighty-five per cent of the eggs hatched.

In two control lots of 20 ticks each, collected on September 27, 1912, all oviposited. A normal number of eggs were deposited; 92 and 80 per cent of the eggs hatched.

Summary of tests in which engorged ticks were dipped in oils.

Date of test.	Mortality.	Ticks ovipositing.	Number of eggs deposited.	Eggs hatched.	Oil used.
	Per cent.	*Per cent.*		*Per cent.*	
September 27, 1912	40	55	Small	(1)	Beaumont oil.
Do	5	100	Normal	90	Cottonseed oil.
Do	0	100	.....do	92	(Control.)
Do	0	100	.....do	60	Do.
Do	[2] 40	65	Few	(1)	Beaumont oil.
September 28, 1912	[3] 0	....	Normal	85	Cottonseed oil.
September 27, 1912	0	100	.....do	92	(Control.)
Do	0	100	.....do	80	Do.

[1] Less than 1 per cent.
[2] Others became abnormal in appearance.
[3] One tick (5 per cent) became abnormal in appearance.

In the foregoing table it is noted that the mortality in the case of ticks dipped in Beaumont oil was 40 per cent in both tests, and in the case of ticks dipped in cottonseed oil it was 5 per cent and 0 per cent. Beaumont oil is therefore shown to have a greater destructive action than cottonseed oil, and this is probably due largely to a toxic action of some kind, since in the tests in which the spiracles were touched with Beaumont oil this oil was shown to be much less effective than in the present tests. Beaumont oil reduced the percentage of females ovipositing and the number of eggs deposited. Cottonseed oil had no influence on oviposition or on the number of eggs deposited. The percentage of eggs hatching in the case of the ticks dipped in Beaumont oil was very low—less than 1 per cent—while the percentage hatching in the case of those dipped in cottonseed oil was practically normal. This would seem to be further evidence of the absorption of Beaumont oil and its toxicity, although it should be stated that it is likely that a part of the lack of viability may have been due to the eggs coming directly in contact with the oil on the bodies of the ticks.

THE EFFECT OF ARSENIC ON TICKS.

Arsenic acts on ticks entirely as a result of its toxic properties. The avenues by which the arsenic gains entrance to the bodies of ticks have not been determined. As pointed out in Bulletin 144, Bureau of Animal Industry, the possible ways are (1) through the mouth; (2) through the breathing pores; (3) through other openings of the body; or (4) by absorption through the cuticle. Arsenic in entering by way of the mouth may enter in two ways, namely, directly, or indirectly through the blood or lymph. Under other openings of the body may be mentioned the anus, the genital pore in adult ticks, the cephalic gland in the female and nymph, and glandular openings in the cuticle.

It is not likely that any dip enters the body through the anus or genital openings, as these are kept tightly closed. The cephalic gland, located beneath the scutum and having its opening situated in the soft chitin between the scutum and the base of the rostrum, offers a possible point of entrance. This gland secretes a viscous fluid which causes the eggs to adhere together and protects them from loss of moisture by evaporation. Anything that would interfere with the function of this gland would affect materially the viability of the eggs deposited. The openings of the tegumentary glands, which are numerous, furnish another means of entrance of arsenic through the chitinous covering of the body.

The porose areas, two in number, located on the dorsal side of the base of the rostrum, furnish another possible point of entrance in the case of adult females. According to Bonnet[1] the punctations of these areas are pores passing through the chitin, each of which communicates with an exposed nerve cell lying beneath the chitinous covering, and which is the termination of one of the fibers of a nerve adjacent to the area. As these nerve cells are without cell membranes and are unprotected in any way, it would appear that the porose areas constitute a most vulnerable point in the body of the tick for the entrance of arsenic.

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[1] Bonnet, Amédée. Recherches sur l'anatomie comparée et le développement des ixodidés. Annales de l'Université de Lyon, n. s., I: sc. méd., fasc. 20. Lyon and Paris.

CATTLE-DIPPING EXPERIMENTS TO ASCERTAIN THE PROTECTIVE ACTION OF ARSENICAL DIPS.

EXPERIMENT NO. 1.—CATTLE EXPOSED TO INFESTATION AT VARIOUS INTERVALS FROM A FEW HOURS TO FOUR WEEKS AFTER DIPPING.

In this experiment the arsenical dip used was made on April 9, 1912. No pine tar was used, for the purpose of avoiding any repellent action that it might contribute to the dip. The dip was made in the usual way, the formula being 8 pounds arsenic trioxid and 24 pounds of sodium carbonate to 500 gallons of dip. Samples of the dip were taken on three dates for analysis. The analyses[1] follow:

Analyses of arsenical dip used in experiment No. 1.

Date.	Actual As_2O_3.	Total As_2O_3.
1912.	*Per cent.*	*Per cent.*
Apr. 29	0.1847	0.1851
May 16	.1841	.1901
June 20	.1229	.2022

It is seen that at the time of the first dipping there was present in the bath 0.1847 per cent of As_2O_3 and a total amount of arsenic equivalent to 0.1851 per cent of arsenic trioxid, and on June 20, two days after the last dipping, 0.1229 per cent of As_2O_3 and a total amount equivalent to 0.2022 per cent arsenic trioxid. The actual amount of As_2O_3 present had decreased during the course of the dipping about one-third through oxidation, and the percentage of total arsenic had increased slightly as a result of evaporation.

Each animal was kept in the dip two minutes.

There were 12 animals (calves) in the experiment, all being northern cattle (nonimmune). Each animal was infested with the seed ticks hatched from 2½ grams of eggs. The seed ticks used were the progeny of engorged females (*Margaropus annulatus*) collected at Fort Worth, Tex., May 3, 1912.

Previous to the time the calves were infested they were kept in a yard provided with shelter, which they might seek when they desired. On the day of infestation (June 18) they were removed to another yard where there was no shelter and kept there until the following noon, when they were placed under cover, where they remained until the close of the experiment. During the night and the forenoon following infestation the animals were out in a light rain.

Lot 1. Calves Nos. 942 and 947.—June 18, 1912, the calves were dipped once in an arsenical dip containing a total amount of arsenic equivalent to 0.2022 per cent As_2O_3 and containing arsenic in the form of As_2O_3 to the extent of 0.1229 per cent. Each calf, as soon as dry, was infested with seed ticks. They were kept under observation until July 22. No ticks developed, and there was no fever.

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[1] All analyses referred to in this bulletin were made by the Biochemic Division of the Bureau of Animal Industry.

Lot 2. Calves Nos. 939 and 941.—The calves were dipped four times at intervals of two weeks, on May 7 and 21, and June 4 and 18, in an arsenical dip. They were infested with seed ticks on the date of the last dipping as soon as they were dry. They were under observation until July 22. No ticks developed, and there was no fever.

Lot 4. Calves Nos. 940 and 944.—These were dipped four times at intervals of two weeks (April 30, May 14 and 28, and June 11) in an arsenical dip. On June 18, one week after the last dipping, they were infested with seed ticks. Both animals became infested with ticks and developed Texas fever. Calf 940 died of the fever July 9. This animal became heavily infested with ticks, and at the time of death most of the ticks had molted the second time. A few nymphs were present. The adult ticks ranged from those just molted to some about one-third engorged. Calf 944 became only lightly infested with ticks. Nine hundred and six adult ticks were collected, the last ones being removed on July 30. The animal recovered from the fever.

Lot 5. Calves Nos. 948 and 949.—These were dipped in an arsenical dip four times at intervals of two weeks, on April 23, May 7 and 21, and June 4. Two weeks following the last dipping, that is, on June 18, they were infested with seed ticks. Both contracted Texas fever, and No. 948 died July 11. This calf became moderately infested with ticks. At the time of death most of the ticks were in the adult stage and ranged from the newly molted to the engorged condition. Calf 949 became heavily infested with ticks. The last adults were removed August 1. In all, 4,884 ticks were collected from this animal.

Lot 6. Calves Nos. 943 and 945.—This lot was dipped four times (April 9 and 23, May 7 and 21), at intervals of two weeks, in an arsenical dip. Four weeks after the last dipping (June 18) they were infested with seed ticks. Calf 943 became heavily infested with ticks and calf 945 acquired a moderate infestation. Both contracted Texas fever, and calf 945 died July 8. The stages present were nymphs and young adults. In the case of calf 943 the last tick was collected on August 3, and in all 5,715 ticks were removed.

Lot 3 (control). Calves Nos. 946 and 950.—These animals were not dipped. They were infested with seed ticks on the same date as the other lots (June 18). Both animals became heavily infested with ticks and contracted Texas fever. Calf 946 died July 6. It was heavily infested with nymphs and young adults. Calf 950 was nearly dead July 15 and was killed. Up to the time the animal was killed, 2,960 adult ticks had been collected.

OBSERVATIONS ON ENGORGED TICKS REMOVED FROM THE ANIMALS.

These ticks were kept in Petri dishes.

Ticks removed from calf 944 (lot 4).—July 12, 70 engorged and nearly engorged ticks removed. All but one of the ticks deposited eggs. A good many eggs shriveled. Most of the ticks died either without ovipositing or before oviposition was completed. About 60 per cent of the eggs hatched.

July 15, 13 engorged ticks removed. All but one oviposited. Some eggs shriveled. Thirty-one per cent of the ticks died either without ovipositing or before oviposition was completed. About 10 per cent of the eggs hatched.

July 16, 55 engorged and nearly engorged ticks removed. All oviposited except four. Sixty-four per cent of the ticks died either without ovipositing or before oviposition was completed. About 95 per cent of the eggs hatched.

July 17, 15 engorged ticks removed for study. All oviposited. Seventy-three per cent of the ticks died before oviposition was completed. About 10 per cent of the eggs hatched.

July 18, 20 engorged females removed. All oviposited. Sixty per cent died before oviposition was completed. About 50 per cent of the eggs hatched.

July 19, 25 engorged and nearly engorged ticks removed. All but one oviposited. Small number of eggs deposited. Eggs were scattered and many shriveled. Twenty-four per cent of the ticks died either without ovipositing or before oviposition was completed. Less than 1 per cent of the eggs hatched.

Ticks removed from calf 949 (lot 5).—July 12, removed 336 engorged and nearly engorged ticks. Lot No. 1 of 100 ticks: All but two oviposited. About half of the ticks died either without ovipositing or before oviposition was completed. About 95 per cent of the eggs hatched. Lot No. 2 of 100 ticks: All but one oviposited. About 50 per cent of the ticks died either without ovipositing or before oviposition was completed. About 95 per cent of the eggs hatched. Lot No. 3 of 136 ticks: All but three oviposited. About half of the ticks died either without ovipositing or before oviposition was completed. About 90 per cent of the eggs hatched.

July 15, removed 49 engorged ticks. All oviposited. About 33 per cent of the ticks died before oviposition was completed. About 95 per cent of the eggs hatched.

July 16, removed 119 engorged females. All but six oviposited. About 65 per cent of the ticks died either without ovipositing or before oviposition was completed. About 85 per cent of the eggs hatched.

July 17, removed 30 engorged ticks. All oviposited. About 30 per cent died before oviposition was completed. About 90 per cent of the eggs hatched.

July 18, removed 30 engorged females. All oviposited but one. Forty-three per cent died either without ovipositing or before oviposition was completed. About 95 per cent of the eggs hatched.

July 19, removed 118 engorged and nearly engorged females. All oviposited. About 33 per cent died before oviposition was completed. About 90 per cent of the eggs hatched.

Ticks removed from calf 943 (lot 6).—July 12, removed 200 engorged and nearly engorged ticks. Lot No. 1 of 100 ticks: All but five ticks oviposited. About 65 per cent of the ticks died either without ovipositing or before oviposition was completed. About 95 per cent of the eggs hatched. Lot No. 2 of 100 ticks: All oviposited. About half of the ticks died before oviposition was completed. About 95 per cent of the eggs hatched.

July 15, removed 35 engorged ticks. All oviposited but one. More than half of the ticks died either without ovipositing or before oviposition was completed. About 95 per cent of the eggs hatched.

July 16, removed 116 ticks. All but five oviposited. About half of the ticks died either without ovipositing or before oviposition was completed. About 95 per cent of the eggs hatched.

July 17, removed 20 engorged females. All oviposited. Thirty per cent of the ticks died before oviposition was completed. About 25 per cent of the eggs hatched.

July 18, removed 30 engorged ticks. All but one oviposited. Ten per cent of the ticks died either without ovipositing or before oviposition was completed. About 75 per cent of the eggs hatched.

July 19, removed 49 engorged and nearly engorged females. All but one oviposited. Fourteen per cent of the ticks died either without ovipositing or before oviposition was completed. About 50 per cent of the eggs hatched.

Ticks removed from calf 950 (lot 3, control).—July 12, removed 200 engorged and nearly engorged ticks. Lot No. 1 of 100 ticks: All oviposited. Ninety-seven per cent of the ticks died before oviposition was completed. About 90 per cent of the eggs hatched. Lot No. 2 of 100 ticks: All but one oviposited. Ninety-five per cent of the ticks died either without ovipositing or before oviposition was completed. About 90 per cent of the eggs hatched.

July 15, removed 26 engorged and nearly engorged ticks. All but one oviposited. Most of the ticks died either without ovipositing or before oviposition was completed. About 90 per cent of the eggs hatched.

DISCUSSION OF RESULTS.

Effect on the animals.—It is noted from the above results that cattle dipped four times at intervals of two weeks in an arsenical dip (lot 2) and subjected to infestation as soon as dry following the last dipping were protected from infestation. It was found that cattle dipped only once (lot 1) and subjected to infestation as soon as dry were likewise protected from infestation. It is therefore seen that arsenic absolutely protected animals from infestation when exposed immediately following a dipping and that one dipping was just as effective in producing this result as a number of dippings at intervals of two weeks. Since none of the animals contracted Texas fever, we are led to conclude that the ticks failed to infect the animals before they were killed by the arsenic.

It was also found that cattle dipped four times at intervals of two weeks and infested one (lot 4), two (lot 5), and four weeks (lot 6) after the last dipping, became infested with ticks and all contracted Texas fever. Of the six animals in these lots, three (50 per cent) died of fever, whereas, as already mentioned, there was no fever or deaths in the lots infested immediately after dipping. In the control lot (lot 3) both animals became infested with ticks and died of Texas fever.

Effect on the ticks.—Observations were made from time to time on the animals for the purpose of noting any ticks that might show evidence of arsenical poisoning. Only a very few dead and abnormal ticks were found. A few dead females were noted on calf 949, a good many abnormal young females, and a few dead ticks on calf 943, and some abnormal young females on calf 945. It is possible that these ticks were affected by arsenic absorbed from the skin of the animal, but their number, compared with the total number of ticks present, was so small that it may be said that the arsenic, if active at all, had a negligible effect on the nymphal and adult stages of the tick. Whether this was also true of the larval stage of the tick can not be said, since it was not practicable to make observations on this stage on account of their small size and the difficulty in finding them.

An interesting abnormality was found in some engorged females taken from two of the dipped animals. Ten of them were taken from calf 949 and one from calf 943. These ticks were plump and transparent. The dark intestinal branches and the Malphigian tubes could be plainly seen lying in the lower portion of the body cavity. On puncturing the body wall a clear fluid issued from the body cavity. Five of the ticks from calf 949 were set aside for special observation. All began ovipositing, but egg-laying progressed very slowly and only a few eggs were deposited. None of the eggs hatched, although some of them developed nearly to the point of hatching.

Nothing final was determined with regard to whether there is any relation between the number of ticks developing on animals and the duration of the interval elapsing between the last dipping and the date of infestation.

For the purpose of obtaining data on this point approximately the same number of ticks were placed on all the cattle—that is, larvæ that hatched from 2½ grams of eggs. In the case of the two animals infested one week after the last dipping (lot 4), one became heavily infested and the other lightly infested; in the case of those infested two weeks after the final dipping (lot 5), one became moderately infested and the other heavily infested; and in the case of the two animals infested four weeks after the last dipping (lot 6), the result was the same, one becoming heavily infested and the other moderately infested. The two control animals became heavily infested with ticks.

An attempt was made to obtain additional and more definite information on the above point by collecting as far as possible all the engorged ticks maturing on the animals. This was interfered with, however, by the death of five of the eight animals that became infested, including the two control animals. The results from the three animals that survived are as follows:

Number of engorged female ticks collected from surviving animals.

No. of animal.	Interval between last dipping and infestation (weeks).	Number of engorged females collected.
944	1	906
949	2	4,884
943	4	5,715

While it would appear from this that the infestation becomes intensified as the interval increases following the last dipping, the data are not adequate for drawing conclusions on this point.

The observations made on the engorged females removed at intervals from the animals (p. 17) were for the purpose of determining whether any arsenic absorbed by the tick might destroy it after it had dropped from the host, or, failing this, whether it would influence oviposition or affect the viability of the eggs.

The results on mortality obtained from the ticks collected from four animals are as follows:

Lot 4 (calf 944), about 50 per cent died.
Lot 5 (calf 949), about 40 per cent died.
Lot 6 (calf 943), about 50 per cent died.
Lot 3 (calf 950, control), about 95 per cent died.

It is noted that the mortality of the ticks from the undipped control animal is higher than for the dipped animals. The mortality in all cases is abnormally high and is very likely due to the fact that all of the animals suffered from Texas fever, and this, either because of the well-known changes in the blood or some other cause, such as, for example, an excessive invasion with *Piroplasma bigeminum*, had a deleterious effect on the ticks. The results, therefore, do not make it possible to draw any conclusions with regard to what part, if any, arsenic played in the mortality.

After obtaining the above results the writer made some observations on engorged females collected from undipped animals suffering from Texas fever in an experiment conducted by Drs. Schroeder and Cotton, of the Bureau of Animal Industry. The data obtained from these ticks are as follows:

Mortality of engorged ticks collected from animals suffering from Texas fever.

No. of animal.	Number of ticks removed.	Mortality.
		Per cent.
808	1,277	10
792	665	12
684	978	7
803	579	17
742	372	32

The mortality here is not nearly as high as in the above instances. Unfortunately, no ticks from animals not suffering from fever were available for controls, but it is known as the result of a wide experience with ticks from normal animals that the mortality is abnormally high.

The percentage of the engorged females that oviposited is given in the following table. The ticks were collected from each animal from July 12 to 19, inclusive, and kept under observation.

Percentage of engorged ticks ovipositing.

Number of animal from which collected.	Number of ticks.	Ticks ovipositing.
		Per cent.
944 (lot 4)	198	96
949 (lot 5)	682	98
943 (lot 6)	450	97
950 (lot 3, control)	226	99

It is noted from the above table that the ticks ovipositing from the dipped animals range from 1 to 3 per cent lower than those from the undipped animal (control). This difference, however, is so slight as to have no significance, and it may be concluded that any arsenic absorbed by the ticks failed to be sufficiently active to prevent oviposition.

The percentage of eggs hatched in the case of the various lots of ticks collected from animals that survived long enough for ticks to mature is as follows:

Percentage of eggs hatching.

Date collected.	Calf 944 (lot 4).	Calf 949 (lot 5).	Calf 943 (lot 6).	Calf 950 (lot 3, control).
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
July 12	60	95, 95, and 90	95 and 95	90 and 90
July 15	10	95	95	90
July 16	95	85	95	....
July 17	10	90	25	....
July 18	50	95	75	....
July 19	1	90	50	....

The percentage in the three dipped animals (944, 949, and 943) ranged from 1 to 95, 85 to 95, and 25 to 95, respectively, as compared with 90 per cent in the three lots from the control animal.

Because of the fact that it was necessary to kill the only remaining control animal (calf 950) on July 15, there were no undipped ticks available for comparison with those collected from the dipped animals on July 16 to 19, inclusive.

By comparing the percentages for the dipped animals with those of the control for July 12 and 15, it is noted that the percentage of eggs hatching from ticks from calf 944, infested one week after dipping, is low, while the percentage for each of the other two animals, infested two and four weeks after dipping, is normal. It is noted that in general the percentages for the remaining dates range lower for calf 944 than for the other animals. Unfortunately the percentages for the dipped animals can not be averaged for purposes of comparison, because the number of eggs in the different lots varied greatly.

It is evident, however, that while arsenic may have been responsible for a decrease in the viability of the eggs in the case of calf 944, there has been no such effect in the case of the ticks from the other two dipped animals, and, on the whole, it seems safe to conclude that arsenic has played no important part in determining the percentage of eggs that hatched.

It should be borne in mind that this result is not contrary to those recorded in Bulletin 144 of the Bureau of Animal Industry, where ticks subjected to the direct influence of arsenic were found to lay eggs that, as a rule, did not hatch. The ticks in the present tests were subjected only to the indirect action of arsenic, as they were not applied as seed ticks until one to four weeks after the animals were dipped.

EXPERIMENT NO. 2.—CATTLE EXPOSED TO INFESTATION TWO AND ONE-HALF HOURS AND TWO DAYS AFTER DIPPING.

After having shown by experiment No. 1 that arsenic has a protective action which lasts for less than a week, it was determined to conduct another experiment for the purpose of determining the length of time that arsenic will protect. It was also thought necessary to repeat the tests showing that arsenic protected against immediate infestation, since there was a possibility that the results obtained might have been accidental. One thing that threw doubt on the last-mentioned result was the fact that the animals, following the last dipping and the infestation (carried out on the same day), were out in a slow rain, which it was thought might have kept the arsenic in solution on the skin and created a condition much as if the ticks had been subjected for some hours to an arsenical dip. In order to obviate this possibility in the following experiment, the dipped animals, as soon as dry, were placed at once under shelter and kept there until the close of the experiment.

In experiment No. 1 the animals were kept submerged in the dip for two minutes. As this is longer than an animal remains in the dip when passing through the ordinary dipping vat, it was determined in the following experiment, in addition to dipping animals for 2 minutes, to dip others for 20 seconds, which comes nearer to the time required to pass through a vat.

The dip used in experiment No. 2 was made on July 29. It was made according to the usual formula of 8 pounds of arsenic to the 500 gallons. An analysis of a sample taken on the date the dip was made showed it to contain 0.1652 per cent arsenic trioxid. As in experiment No. 1, no pine tar was used. Twelve calves were used in the experiment, divided into five lots as described below. All of the cattle were dipped on August 1. Lots 1, 2, and 5 were infested with the progeny of female ticks collected at Fort Worth, Tex., June 24, 1912. Lots 3 and 4 were infested with the progeny of females received from Fort Worth, June 29, 1912.

Lot 1. Calves Nos. 957, 947, and 958.—Dipped two minutes in an arsenical dip. Infested with seed ticks two and one-half hours after dipping. No ticks developed. Calves 957 and 947 developed no fever. Calf 958 showed a temperature and in all probability had an attack of Texas fever. Calf 947 following dipping suffered from anorexia and bloat. On August 26 the animal developed a gastric fistula located on the underside of the abdomen. Food and drops of liquid were issuing from it. On August 29 the animal was killed. The fistula was found to extend into the fourth stomach. The mucous folds in the region of the fistula were hypertrophied, hemorrhagic, and sloughing away. This was clearly a case of arsenical poisoning.

Lot 2. Calves Nos. 927, 939, and 928.—Dipped 20 seconds in an arsenical dip. Infested with seed ticks two and one-half hours after dipping. No ticks developed on these animals. There was no fever. Calf 939 died August 20. On post-mortem there was an enteritis, principally of small intestine and cecum. There was congestion of lungs and a slight congestion of kidneys. Smears from spleen and liver contained no piroplasma.

Lot 3. Calves Nos. 955 and 942.—Dipped two minutes in an arsenical dip. Infested two days after dipping (August 3) with seed ticks. No ticks developed on these animals. Calf 942 showed a rise in temperature from the ninth to the twelfth day after infestation. On August 6 calf 955 died of arsenical poisoning. The liver was yellow (fatty degeneration) and very friable. There were large hemorrhages in the endocardium of the right side, also large hemorrhagic areas in all four stomachs. An enteritis was present. There were edematous areas in wall of stomach and intestine. The capsule of the spleen was much injected. All blood vessels were injected and the blood was very dark. There were no lesions in the mouth.

Found a number of larvæ on the skin, all of which were dead. Two of these were observed with certainty to be attached.

Lot 4. Calves Nos. 956 and 941.—Dipped 20 seconds in an arsenical dip. Infested with seed ticks two days after dipping (August 3).

August 16 found a very young nymph on calf 941.

August 20 removed above tick for examination, and determined that it was a specimen of *Margaropus annulatus*. No other ticks were found. No ticks developed on calf 956. This animal showed a temperature from the sixth to the twelfth day. Calf 941 showed no temperature.

Lot 5 (control). Calves Nos. 926 and 938.—Undipped. August 1 infested with seed ticks. Both of these animals became heavily infested with ticks and showed a rise in temperature. Calf 926 was down August 22. Had been down since the previous day. The animal was greatly emaciated. It was killed. Heavily infested with ticks. There were no lesions of Texas fever. Smears from liver and spleen contained no piroplasma. On August 16 both of the above animals were treated with a subcutaneous injection of 150 c. c. of a 1 per cent solution of trypan blue. Calf 938 was killed August 30 for the purpose of noting whether the stain from the trypan blue still persisted. On post-mortem both carcasses were found to be extensively stained. The parts stained were as follows: The skin; subcutaneous and intermuscular connective tissue; parietal and visceral pleura and the peritoneum; epicardium, endocardium, and pericardium; trachea; bronchi and smaller air tubes; cartilage of joints; capsule and trabeculæ of spleen; cortex of kidneys, and the veins and arteries. A pale-bluish fluid was noted in some of the mesenteric lymph glands.

The post-mortems were made 6 and 14 days after the trypan-blue solution was injected.

DISCUSSION OF RESULTS.

It is noted from the above results that animals when dipped once in an arsenical dip for two minutes (lot 1) and for 20 seconds (lot 2) were protected from infestation when exposed two and one-half hours after dipping. This occurred when the animals were not exposed to rain and the arsenic on the skin was not kept in a more or less dissolved state for some time, as was probably the case in experiment No. 1.

It is also seen (lots 3 and 4) that animals dipped for two minutes and for 20 seconds were protected from infestation when exposed two full days after dipping. It is believed that the one young nymph found 13 days after infestation on calf 941 could not have been a larva that attached itself at the time of infestation, since its stage of development was considerably behind that of a tick nearly two weeks old. It is likely that this tick failed to attach itself, became dislodged from one of the calves after they were placed in the experimental paddock, and some days later succeeded in attaching itself. It is possible, however, that this tick attached itself on the day of infestation. The writer obtained (Bul. 130, Bureau of Animal Industry) in experiments conducted in 1908 a maximum period of 14 days for the larval stage, although it is possible that here also the tick failed to become attached at once. The usual larval period is from five to nine days.

It is noted that both of the control animals became heavily infested with ticks.

DEATH OF ANIMALS FROM ARSENICAL POISONING.

In the above experiment two animals (calves 939 and 955) died from arsenical poisoning, and it was necessary to kill another (calf 947) suffering from a gastric fistula due to arsenical poisoning. A number of the other dipped animals suffered for a time with anorexia, and some had temperatures that were puzzling and could not with certainty be attributed to Texas fever. It is possible that they also suffered from arsenical poisoning. One of the undipped (control) animals became sick, and it was necessary to kill it. The cause of its sickness was not clear, but was very probably Texas fever. Although it showed a temperature, there were no lesions of Texas fever on post-mortem, and the piroplasma could not be demonstrated on microscopic examination. However, six days previously it had been injected with a solution of trypan blue. This treatment may have eliminated the organism, which, if present at all, was probably present in small numbers, as the animal was a calf.

The death of three animals from arsenical poisoning and the sickness of a number of others, due possibly to the same cause, was puzzling to the writer for a time, especially in view of the fact that this bureau had conducted experimental dippings in arsenic for a number of years at the experiment station without a single loss. The analysis of the dip used showed an arsenic content of 0.1652 per cent. This was much too low for the quantity of arsenic used. The percentage of arsenic should have been 0.1925. It is evident that all of the arsenic was not dissolved when the dip was made. The most probable explanation of the poisoning is that there was undissolved arsenic in the dip, and the animals while being dipped swallowed enough to cause poisoning. Support is lent to this view by the fact that much difficulty was experienced in dissolving the arsenic, because the water was not kept boiling. After all the arsenic had apparently gone into solution and the strong solution was added to the water in the vat, clumps of white particles were seen floating in the water. The writer at the time assumed these to be masses of calcium carbonate thrown down by the sodium carbonate. It was shown that this could not have been the case, however, by observations made when the batch of dip was prepared for the next experiment (No. 3). Water from the same source was used, and no such precipitate was thrown down by the sodium carbonate. The only conclusion that remains, and this is supported by the analysis referred to above, is that the particles observed were undissolved arsenic. If the conclusions here drawn with regard to the cause of the poisoning are correct, the extreme danger of having undissolved arsenic in a dip is indicated, and it is possible that an explanation of losses in certain instances has been furnished.

STAINING OF TISSUES OF ANIMALS TREATED WITH TRYPAN BLUE.

The extensive and intense staining of the tissues of animals treated with subcutaneous injections of a 1 per cent solution of trypan blue has been previously noted in the post-mortems of animals Nos. 926 and 938. The post-mortems were made 6 and 14 days after the treatment. It would be of some practical interest to determine how long the staining will persist in treated animals, since it appears that it might interfere with the use of animals for beef purposes for a considerable period.

EXPERIMENT NO. 3.—CATTLE EXPOSED TO INFESTATION FIVE DAYS AFTER DIPPING.

Following experiment No. 2 another was undertaken to determine whether arsenic will protect animals from infestation five days after dipping.

The dip used in experiment No. 3 was made up in the proportions of 8 pounds of arsenic trioxid and 24 pounds of sodium carbonate to 500 gallons of water. No pine tar was used. The dip was made August 29, and an analysis showed it to contain 0.1869 per cent of arsenic trioxid. The results of the experiment were as follows:

Lot 1. Cattle Nos. 830 and 860.—Dipped August 29, 20 seconds. September 4 (five days later) infested cattle with progeny of ticks collected August 8, 1912, at Fort Worth, Tex. Both animals became grossly infested with ticks and contracted Texas fever. On September 20 animal 830 died. Post-mortem showed typical lesions of Texas fever.

Lot 2 (control). Cattle Nos. 855 and 858.—Undipped. September 4 infested with progeny of ticks collected August 8 at Fort Worth, Tex. Both animals became grossly infested with ticks and contracted Texas fever.

DISCUSSION OF RESULTS.

It is shown by the above experiment that animals dipped in an arsenical dip containing 0.1869 per cent of arsenic trioxid are not protected from infestation when exposed five days after dipping. It also appears that the degree of infestation was not influenced in any way by the dipping in arsenic.

THE METHOD BY WHICH ANIMALS ARE PROTECTED AGAINST TICK INFESTATION.

There are two ways in which it is conceivable that arsenic protects against infestation; that is, by rendering the skin unpleasant to the tick, and by poisoning the tick after it attaches. Support is lent to the latter view by the fact that dead larvæ were found attached to the skin of calf 955 at the time of its death three days after it was infested. It was not practicable to multiply observations similar to the above because of the great length of time consumed in locating the seed ticks on the animals.

The results of the experiments, however, have proved conclusively that the protection is due to the larvæ being killed and not to their being repelled. The animals when seed ticks were applied to them were placed in a special pen set aside for that purpose, and several hours later, after the ticks had had time to attach themselves, were placed in the tick-free pens they were to occupy during the experiment. If arsenic possessed simply a repellent action effective for two days, complete protection would not have resulted as occurred in the experiments, since the larvæ would either have wandered about over the hair of the animals or have become dislodged, only to become attached later when the repellent action of the dip had ceased to be effective. It is therefore seen that if we were dealing with a repellent action instead of a toxic action at least a certain degree of infestation must have resulted in the case of all of the dipped animals, unless, of course, all the seed ticks left the animals between the time the ticks were applied and the animals were placed in their permanent pens, a possibility that is too remote to be worthy of consideration.

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